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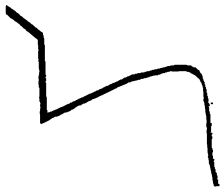

MINERALOGY SIMPLIFIED.

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BY

HENRY ERNI, A. M., M. D.,

SOMETIME CHIEF CHEMIST OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

FOURTH EDITION.

REVISED, REARRANGED, AND WITH THE ADDITION OF ENTIRELY NEW MATTER.

INCLUDING

CRYSTALLOGRAPHY, TABLES FOR THE DETERMINATION OF MINERALS BY CHEMICAL AND PYROGNOSTIC CHARACTERS,

AND

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BY

AMOS P. BROWN, A. M., Ph. D.,

PROFESSOR IN CHARGE OF THE DEPARTMENT OF GEOLOGY AND MINERALOGY IN THE UNIVERSITY OF PENNSYLVANIA.

ILLUSTRATED BY ONE HUNDRED AND TWENTY-THREE ENGRAVINGS.

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PREFACE TO THE FOURTH EDITION.

THE Third Edition of MINERALOGY SIMPLIFIED was so thoroughly revised and rearranged that comparatively few changes were necessary in the preparation of the present edition. In the Preface to the Third Edition I say: "My aim has been to produce a *Determinative Mineralogy* useful alike to the propector and the general mineralogist." With that end in view I introduced Part III on Physical Determinative Mineralogy, by the use of which a mineral collector or prospector may make determinations of most of the minerals he will meet with in the field, without being obliged to resort to chemical tests, and the combination of independent *Chemical* and *Physical* tables in one book enables the mineralogist to check his determination with one set of tables by the use of the other.

The main changes found to be necessary in this edition were mainly in the way of additions. Beyond adding a few species omitted in the Third Edition, the Tables for Determination of Minerals by Chemical Characteristics (Part II) are substantially as in that edition. A few species have been added to Part III also, but the main addition to that portion of the book has been in the extension of the use of the *rubbed streak* as a means of distinguishing minerals by physical properties. All the

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minerals with "black streak" mentioned in the tables have been examined and the distinctive colors of their *rubbed streaks* recorded. In some cases of *colored streaks* also this character has been found to the useful in distinguishing mineral species, the color of the streak changing decidedly upon rubbing.

In the Third Edition, the subject of *Crystallography* received very brief treatment; in this present edition an entire new chapter (Chapter II) has been devoted to the principles of crystallography, and it is illustrated by original drawings prepared expressly for this edition. While the treatment is necessarily brief, it is believed that the principles are set forth with sufficient clearness to enable a student (with the aid of a set of *crystal models*) to acquire enough acquaintance with the subject to make use of the physical tables. The subject of *cleavage*, a character depending upon crystal structure, has also received a more extended treatment in this edition; this being rendered necessary by the new chapter on crystallography. This will be found in the Introduction to the Chemical Tables, Part II.

It is hoped that the pocket size and form of the book will commend itself to the prospector and field mineralogist, and the ample table of contents and full index will make references easy and satisfactory.

AMOS P. BROWN.

UNIVERSITY OF PENNSYLVANIA.
September 12, 1908.

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APPENDIX I.

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MINERALOGY SIMPLIFIED.

PART I.

GENERAL PRINCIPLES, METHODS AND REACTIONS.

CHAPTER I.

General Principles of Mineralogy.

A mineral is a naturally occurring body produced by inorganic processes, which possesses a definite chemical composition and a definite molecular structure. This definite molecular structure is manifested in the crystalline form, the cleavage, and the behavior of the mineral towards transmitted light and heat. A *mineral* is homogeneous in composition and structure, in contradistinction to a *rock* which is generally a mixture of different mineral species, and always an aggregate of mineral individuals, and hence is heterogeneous in composition, or structure, or both.

As chemical substances, minerals are either the native elements or compounds of the elements. *The chemical element* is a substance that cannot be further decomposed by any known process. More than seventy *such elements* have been recognized.

The smallest portion of any element that can enter into a chemical combination is called the *atom;* the smallest portion of any element or compound capable of existing in the free state, and of displaying the characteristics of the element or compound, is called the *molecule.* It is entirely possible that the molecules of a solid substance may be larger and more complex than those of the same chemical substance in the form of a gas or vapor; the composition as given for the chemical molecule has reference, really, to the molecule in the gaseous state.

In forming compounds, chemical elements unite with each other in various definite proportions by weight, this relation being expressed by the terms *atomic weight,* or *atomic mass.* In the table of atomic weights given in the Appendix they are expressed on the basis of the atomic weight of oxygen (O) = 16. For convenience in writing chemical formulæ, the elements are designated by *symbols,* which are contractions of the name of the element, including the initial and perhaps one other letter. The composition of a substance is then expressed as a *formula,* in which the number of atoms of each element entering into the combination is given by figures, written as subscripts after the symbol of the element; for example, H_2O, the symbol of water, indicates two atoms of hydrogen combined with one of oxygen. The sum of the atomic weights of the elements composing a substance is called the *molecular weight;* thus the molecular weight of water is $H = 1 \times 2$ plus $O = 16$, or $H_2O = 18$. Combinations of the elements with oxygen are called oxides; combinations of the metallic elements with hydrogen and oxygen together

are in general called *bases*, while the combinations of the non-metallic elements with hydrogen and oxygen, or certain of them with hydrogen alone, are in general called *acids*. A *salt* is the compound produced by the interaction of an *acid* and a *base* upon one another, and results from the total or partial replacement of the hydrogen of the acid by the metal of the base. Salts are formed equally well by the action of an acid upon a metal. Such interactions or *reactions*, expressed in the symbols of the compounds involved, become chemical equations; for example:

(1) $H_2SO_4 + FeCO_3 = FeSO_4 + CO_2 + H_2O$.
(2) $H_2SO_4 + Fe = FeSO_4 + H_2$.

In the first example sulphuric acid acts upon siderite or carbonate of iron, forming ferrous sulphate, water and carbon dioxide; in the second case, the acid acting upon metallic iron produces as before ferrous sulphate or copperas, and hydrogen is evolved.

By quantitative analysis it is possible to determine the percentage composition of the compound, expressed in terms of the percentages of the elements in the compound by weight; knowing the atomic weights of the elements, or the relative masses of their atoms, the chemical formula may be calculated from this percentage composition. Conversely, the percentage composition corresponding to any formula may be calculated. In qualitative analysis, however, the combination of elements in a compound is made out without determining their relative quantities; and hence the mineral is recognized, by qualitative analysis, only by this combination of elements. In such cases the physical

properties must be considered, in addition to the chemical properties, in drawing conclusions as to species.

It is a matter of observation that substances possessing analogous chemical composition are liable to show a similarity in their crystalline form and structure: such substances are said to be *isomorphous*. For example, the carbonates of Ca, Mg, Mn, Fe, Zn, all crystallize in the hexagonal rhombohedral form, with a strong cleavage parallel to a rhombohedron of almost identical angle throughout the series. Further, such substances may crystallize together and the resulting mixed salt has physical properties intermediate between its limiting salts. Thus breunnerite is intermediate between siderite, $FeCO_3$, and magnesite, $MgCO_3$, and its formula is written $(Fe, Mg)CO_3$, which means $nFeCO_3 + mMgCO_3$.

Calcium carbonate occurs in two forms; as calcite, hexagonal rhombohedral, and as aragonite, orthorhombic. Such chemical combinations, which occur in several crystalline forms, are described as *dimorphous*, *trimorphous*.

NOTE.—A table of the Chemical Elements, their Symbols and Atomic Weights, will be found in the Appendix.

A. P. B.

CHAPTER II.

The Principles of Crystallography.

It has been stated that a mineral possesses not only a definite chemical composition, but also a definite internal structure, which consists of an orderly arrangement of the atoms of the elements of which it is composed, as well as of the crystal molecules into which these atoms are aggregated. From this it follows, that when the mineral deposits under conditions favorable for the development of individuals, there result solids bounded by planes, arranged in definite relation to each other, and such individuals are called crystals. A crystal is then, in its most perfect form, a mineral individual possessing a regular polyhedral shape, that is conditioned by the orderly arrangement of the particles of which it is composed.

When, on the other hand, the mineral substance solidifies under conditions in which the orderly arrangement of its particles is impossible, as when a fusion passes rapidly through a viscous state to a glass, or a jelly separates from solution and solidifies by loss of water, the substance becomes amorphous. In the amorphous condition there is no definite, orderly arrangement of the particles of the substance.

It will readily be seen that as the atoms of the elements tend to combine into definite molecules, and as

these molecules tend to aggregate into individuals with definite, orderly arrangement, the crystalline condition is the normal one and the amorphous condition is exceptional. Each individual mineral substance tends to assume a form which is characteristic of that substance and which is an expression of its definite molecular structure. The crystal of any substance is then characteristic of that substance, and hence a knowledge of crystal morphology is of great importance in the study of mineral species.

Looked at from the standpoint of its morphology, a crystal is a solid bounded by planes, which are arranged symmetrically with respect to a *point*, or to a *line* or lines, or to a *plane* or planes. The point is called a *center of symmetry*, the lines are called *axes of symmetry* and the planes are called *planes of symmetry*. From a study of the relation of the crystal planes to these points, lines or planes, or to each other, it is found that all planes appearing in the crystals of any given substance can be connected by a simple law called the *Law of the Simple Mathematical Ratio*. That is, the different kinds of faces on a crystal are related to each other by simple integral ratios. Moreover, in any given substance, the corresponding planes on different individuals of that substance always make the same interfacial angles with each other.

The crystals of any given substance are therefore characterized by:

(1) Symmetry.

(2) Simple integral ratios between the different kinds of faces.

(3) Constancy of corresponding interfacial angles.

In order to express the relation of the planes of a crystal to each other, they are referred to certain axes of reference, or *crystal axes*, usually three in number; and the position of the plane in space may be expressed by establishing a ratio between the relative distances from the center to the points in which the plane cuts these crystal axes. These distances from the center to the points where the plane cuts the axes (usually expressed in terms of an axial ratio) are called the *parameters* of the plane, and the symbol of any crystal form might be written in terms of these parameters. More commonly, however, the symbol of any form is given in terms of its *indices*, which are the reciprocals of the parameters. For example, in the cube, the *crystal axes* are the normals to the faces, passing through the center of the cube. The *parameters* of any face of the cube are unity (1), infinity (∞), and infinity (∞), the face being parallel to two axes, and hence only meeting them at infinity. The *symbol* of the face, expressed in terms of the *parameters*, would be $1:\infty:\infty$; but, in terms of the *indices*, it would be (100). The general expression for any form, in terms of its indices, would be (*hkl*), where *h*, *k* and *l* are the indices of a plane of the form. Either one or two of the three terms may be a variable multiple, or may be zero (or infinity, in the symbol expressed in terms of the parameters); from which it follows that there are seven different forms in each possible crystal group or class, designated by seven ratios, which, in terms of the indices, are as follows: (100), (110), (111), (*hkk*), (*hhl*), (*hk*0), (*hkl*); in which the symbols *h*, *k* and *l* may be any simple whole numbers, *usually under 10.* For example (*hkl*) might be (321),

(432), (532), etc., and all of these would be the same general form, and designated by the same general name, but distinguished by the differences in the indices. The forms described under the different systems will be expressed in terms of their *indices*.

The symmetry of the planes of the different crystal forms with respect to their axes of reference permits of the classification of these forms into six *crystal systems*, characterized by the following development:

I. ISOMETRIC.—Equal development in three directions at right angles to each other.

II. TETRAGONAL.—Equal development in two directions at right angles, with unequal development along a third direction at right angles to the plane of these two.

III. HEXAGONAL.—Equal development in three directions (in one plane) at 120° to each other, with unequal development along a fourth direction at right angles to the plane of the other three. This system is divided into the *Hexagonal Section*, with the unequal axis an axis of *hexagonal* symmetry, and the *Rhombohedral Section*, with the unequal axis an axis of *trigonal* symmetry.

IV. ORTHORHOMBIC.—Unequal development in three directions at right angles to each other.

V. MONOCLINIC.—Unequal development in three directions, two of which are not at right angles to each other, but the third of which is at right angles to the plane of the other two.

VI. TRICLINIC.—Unequal development along three axes, none of which are at right angles to each other.

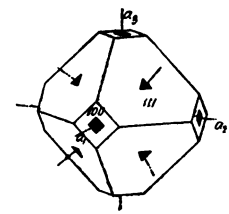
In each *system* several grades of symmetry are possible, all of which grades of symmetry still conform to

the characteristic development of the *system*. These smaller divisions of the *system* are known as *classes* or *groups*. The highest grade of symmetry in any system is called the *Normal Group* and those of lower grade are designated by descriptive names expressing some characteristic of the group. For example, in the Isometric system, the octahedron expresses the highest grade of symmetry, and is an example of the *normal* group; the tetrahedron, with the same symbol, but a lower grade of symmetry, belongs to the *tetrahedral* group. By considering the character of the symmetry of the *crystal axes*, and the presence or absence of *planes of symmetry* in certain positions, it is possible to classify the symmetry of the different groups, so that any given crystal may be readily referred to its group, by a consideration of its symmetry with reference to certain axes and planes. The more important crystal groups are given, in each case, in the discussion of the six several crystal systems.

I. THE ISOMETRIC SYSTEM.

This system is characterized by equal development in three directions at right angles, the directions of the three crystal axes of reference, a_1, a_2, a_3, Fig. 1, and by the possession of four trigonal axes inclined to each other at 70° 31′ 44″, the normals to the faces of the octahedron (Fig. 1). There are five groups in this system, of which the Normal group, the *Pyritohedral group* and the Tetrahedral group are

FIG. 1.



the most important. Their symmetry may be summarized as shown in the following table, in which the symmetry of the crystal axes, of the planes of the crystal axes, and of the trigonal axes with one crystal axis is given :

Group.	Crystal axes.	Axial planes.	Intermediate planes.
Normal.	◆	S	S
Pyritohedral.	⬬	S	N
Tetrahedral.	⬬	N	S

The Normal Group. Examples: Galenite, garnet.

In this group, as will be seen from the table, the crystal axes are quaternary (◆), the axial planes are planes of symmetry (S), and the intermediate planes are planes of symmetry. Figure 1 represents a crystal of this group, a combination of the octahedron (111) and the cube (100). The crystal axes of reference are the normals to the cube faces, and the trigonal axes are the normals to the octahedron faces.

Seven forms are distinguished in this group, as follows:

1. Octahedron (111).
2. Cube (100).
3. Rhombic dodecahedron (110).
4. *Trapezohedron* (*hll*), (211), (311), (322), etc.

5. Trisoctahedron (*hhl*), (221), (331), (332), etc.
6. Tetrahexahedron (*hk*0), (210), (320), (310), etc.
7. Hexoctahedron (*hkl*), (321), (421), (531), etc.

The *octahedron* (111) is shown in Fig. 2, and consists of a solid bounded by eight equal, equilateral triangles, inclined to each other at about 109° 28′, or 70° 32′ measured over a point. When the faces are unequally developed they become six-sided, but the plane angles of the edges are always 60° and the interfacial angles

FIG. 2.

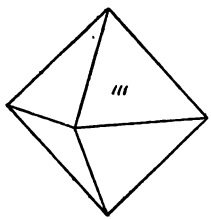
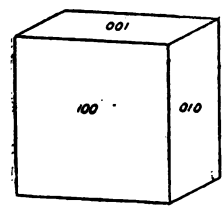


FIG. 3.



are constant. Galenite, fluorite, magnetite and spinel crystallize in octahedrons.

The *cube* (100) is shown in Fig. 3. Its six square or rectangular faces make angles of 90° with each other, and the plane angles of the edges of the faces are 90°. Cubes may elongate along any one axis and then look like square prisms, or they elongate on two axes, becoming tabular. Galenite, the simple chlorides and fluorite crystallize in cubes.

The *dodecahedron* (Fig. 4) is bounded by twelve equal faces with plane angles of 109° 28′ and 70° 32′ between the edges of the faces, and these faces meeting in dihedral *angles of 120°* with each other, or 90° over the

point of an axis. When the planes of the crystal are unequally developed, it may elongate along the crystal axes or the trigonal axes, becoming apparently tetragonal, orthorhombic or rhombohedral. A common example of the dodecahedron is the mineral garnet.

FIG. 4.

FIG. 5.

The *trapezohedron* (*hll*) is also a common crystal in garnet, in which usually the form is (211) (Fig. 5). In many minerals, this form is more commonly found in combinations with the simpler forms above mentioned.

The *trisoctahedron*, *tetrahexahedron* and *hexoctahedron* usually occur in combinations.

The three simple forms without variable multiples in their symbols, the cube (100), the octahedron (111) and the dodecahedron (110), are the three directions in which cleavage commonly occurs in this system.

The Pyritohedral Group. Examples: Pyrite, cobaltite.

In this group the crystal axes are binary ( ), the axial planes are planes of symmetry, and the intermediate planes are not planes of symmetry. Fig. 6 represents a crystal of pyrite, which shows the symmetry of the group. This is a combination of the cube (100) and the pyritohedron (210); the crystal axes, normal

to the cube faces, are seen to be binary; the planes passing through these axes, taken in pairs, are planes of symmetry for the combination. The trigonal axes are not shown, but occupy the same position as in Fig. 1. The only forms in this group that differ from the corresponding forms in the normal group are the diploid (*hkl*) and the pyritohedron (*hk*0). All other forms are the same as in the normal group. For instance, the combination shown in Fig. 7, which represents a common crystal in pyrite, shows the pyritohedron (210) in combination with the octahedron (111), and

FIG. 6.

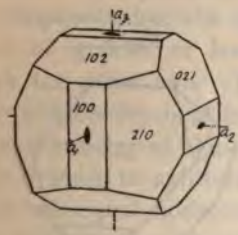


FIG. 7.

the planes of this latter form are the same in number and in position as those of the normal group. The *pyritohedron* (*hk*0) frequently occurs alone, as well as the principal form in the combination, but it may be reduced to mere striations on the faces of the cube, which striations then show the symmetry of the pyritohedral group, being parallel on opposite cube faces and at right angles on adjacent cube faces. The *diploid* (*hkl*) rarely occurs as a single form; it is usually seen in combination with the cube, octahedron, pyritohedron, *etc.; it is a figure* with twenty-four faces, corresponding

in position to half of the faces of the hexoctahedron (*hkl*).

The Tetrahedral Group. Examples: Tetrahedrite, sphalerite. In this group the crystal axes are binary (⬬), the axial planes are not planes of symmetry, but the intermediate planes are planes of symmetry. The geometric tetrahedron shows the symmetry of the group (fig. 8). The forms, not the same as those of the normal group, that occur in this group, are all that possess only finite parameters. These forms are the tetrahedron (111), shown in figs. 8 and 9, the latter in combination with the dodecahedron (110); the trigonal tristetrahedron (211), etc.; the tetragonal tristetra-

FIG. 8.

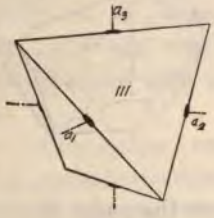


FIG. 9.

hedron (221), etc., both of which have twelve faces; and the hexatetrahedron (*hkl*), (321), etc., which is a form with twenty-four faces. All of these show a strong tetrahedral habit. Minerals crystallizing in this group, which are non-conductors of electricity, usually develop static electricity of opposite polarity at the two ends of each trigonal axis, when heated and allowed to cool (*pyro-electricity*).

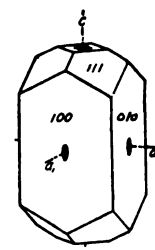
It will be noticed that the opposite ends of the trig-

onal axes in this group are *unlike;* one end emerges at the point of the tetrahedron, the other end in the middle of the equilateral triangular face (compare Fig. 8). This character is described as *hemimorphism*, and the tetrahedral group may be said to be *hemimorphic* on the trigonal axis. Pyro-electricity is, in general, exhibited by non-conductors, of any system of crystallization, which show this hemimorphic development.

II. THE TETRAGONAL SYSTEM.

The tetragonal system is characterized by development in three rectangular directions, two of which are directions of equal development, but the third is a direction of greater or less development than the other two. The direction of unequal development is made vertical. The symmetry of the *normal group* in this system is exhibited in Fig. 10. The two equal horizontal axes, a_1, a_2, are binary, the principal or vertical axis c is quaternary. The horizontal axial plane is a plane of symmetry, the vertical axial planes are planes of symmetry, and the vertical intermediate planes are planes of symmetry. Looked at in the direction of the *vertical axis*, such a crystal is seen to have its faces and angles arranged in *fours* about this axis. The lateral axes, taken as axes of reference, *crystal axes*, are interchangeable with the axes at 45° with them, the *intermediate axes*, and these latter are binary, like the crystal axes. Of the seven groups recognized in this system, the more important are given in the following table:

FIG. 10.



Group.	Vertical axes.	Lateral axes.	Horizontal axial plane.	Vertical axial planes.	Vertical intermediate planes.
Normal	◆	⬬	S	S	S
Pyramidal	◆	—	S	N	N
Pyramidal-hemimorphic.	◆	—	N	N	N
Sphenoidal	⬬	⬬	N	N	S

The Normal Group. Examples: Zircon, vesuvianite, rutile.

In this, the principal group of the system, the vertical axis is *quaternary*, the lateral axes are *binary*, and the three axial planes are, as shown in the table, planes of symmetry. Figure 10 shows the symmetry in this group, and is a combination of the second order prism (100), with the unit pyramid (111) and the base (001). The two lateral axes of reference, a_1 and a_2, are binary; the vertical axis, c, is quaternary.

The seven forms in the normal group are as follows:

1. Basal pinacoid, or base (001).
2. Unit pyramids and pyramids of the first order, (111), (*hhl*), (223), etc.
3. Unit prism, first order prism, (110).
4. Second order pyramids (*h*0*l*), (101), (302), etc.
5. Second order prism (100).
6. Ditetragonal pyramids (*hkl*), (321), (121), etc.
7. *Ditetragonal* prism (*hk*0), (310), (210), etc.

Examples of some of these forms are seen in the combinations shown in figures 11 and 12, as well as in figure 10 already mentioned.

Figure 11 shows the combination of the first order prism (110), and the second order prism (100), with the first order or unit pyramid (111). By changing the

FIG. 11.

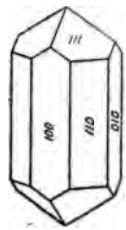
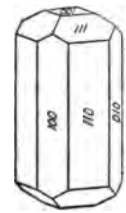


FIG. 12.



position of the crystal axes to 45° from their present position the order of the prisms and pyramids represented would be reversed, and the combination would become the first order prism, and the second order prism and pyramid. Figure 12 shows the same combination of prisms and pyramid with the base.

The ditetragonal prism and pyramid have ratios lying between those of the prisms and pyramids of the first order and the second order, and have twice as many faces in the respective forms as the first or second order forms; that is, the prism has eight faces and the pyramid has sixteen faces.

The other groups mentioned do not occur so commonly as the normal group. The new forms appearing in the pyramidal group can only occur in such ratios as possess variable parameters; that is, in the ratio $(hk0)$ *and* (hkl).

In the *pyramidal* group, four-sided prisms and pyramids with these ratios occur, called the prism of the third order (*hk*0) and the pyramid of the third order (*hkl*). In combinations, these third order pyramids or prisms appear between the faces of the pyramids or prisms of the first and second order. Examples of the pyramidal group are, scheelite and wernerite.

The *pyramidal-hemimorphic* differs from the pyramidal group in being hemimorphic in the direction of the vertical axis; that is, the two ends of the vertical axis show different planes. The horizontal axial plane is hence not a plane of symmetry. An example of this group is the lead molybdate, wulfenite.

The *sphenoidal* group corresponds to the tetrahedral group in the isometric system, having the vertical axis binary, as well as the horizontal axes, and the only planes of symmetry are the vertical intermediate planes. The forms in this group, different from the normal forms, are the tetragonal scalenohedron (*hkl*) and the tetragonal sphenoid (*hhl*), (111). The other forms are the same as those of the normal group. Examples of the sphenoidal group are chalcopyrite and stannite.

III. THE HEXAGONAL SYSTEM.

In the hexagonal system two sections are distinguished, the *Hexagonal* proper, in which the vertical axis is a hexagonal axis, and the *Trigonal* or *Rhombohedral*, in which the vertical axis is trigonal or ditrigonal. The system is characterized by equal development in three directions in one plane, making angles of 120° with each other and by unequal development in a fourth direction at right angles to this plane. It hence

corresponds to the tetragonal system, in having the vertical axis an axis of unequal development, but has *three* axes of equal development in the horizontal plane instead of two, as in the case of the tetragonal system. Twelve groups are distinguished in this system, of which five are *hexagonal* and seven are *trigonal*. The symmetry of the more important of these groups is summarized in the following tables:

Group.	Vertical axes.	Lateral axes.	Horizontal plane.	Vertical axial planes.	Vertical intermediate planes.
Normal			S	S	S
Hexagonal-hemimorphic		—	N	S	S
Hexagonal-pyramidal		—	S	N	N
Rhombohedral			N	N	
Rhombohedral-hemimorphic		—	N	N	S
Rhombohedral-trapezohedral			N	N	N

The Hexagonal Section. Vertical axis horizontal.

The Normal Group. Examples: Beryl, molybdenite.

In *the normal group* the horizontal or lateral axes

are binary, the horizontal plane is a plane of symmetry, and the two sets of vertical axial planes are also planes of symmetry. Fig. 13 shows the symmetry of this group. The vertical axis c is seen to be hexagonal and, when the crystal is examined along this axis, the faces and angles are arranged symmetrically in *sixes* about the axis. The horizontal axes $+a_1$, $-a_3$, $+a_2$, etc., are binary. The forms represented in this figure are the second order prism $(11\bar{2}0)$, the first order pyramid $(10\bar{1}1)$, and the base (0001).

The seven forms of the *normal group* with their symbols are:

1. Basal pinacoid or base, (0001).
2. Unit pyramid and pyramids of the first order, $(10\bar{1}1)$, $h0\bar{h}l$, etc.
3. Unit prism, prism of first order, $(10\bar{1}0)$.
4. Second order pyramids, $(11\bar{2}1)$, $(h.h.\bar{2}h.l)$, etc.
5. Second order prism, $(11\bar{2}0)$.
6. Dihexagonal pyramids, $(hk\bar{i}l)$ $(21\bar{3}1)$, etc.
7. Dihexagonal prisms, $(hki0)$, $(21\bar{3}0)$, etc.

FIG. 13.

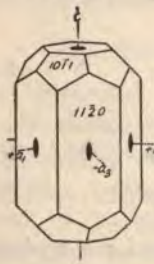
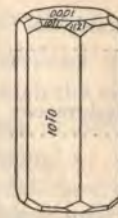


FIG. 14.



Examples of crystals of the normal group are seen in *figs. 13 and 14.* Figure 13 shows the second order

prism $(11\bar{2}0)$, in combination with the first order pyramid, $(10\bar{1}1)$, and the base, (0001). Figure 14 shows the first order prism, $(10\bar{1}0)$, in combination with the first order pyramid, $(10\bar{1}1)$, the second order pyramid, $(11\bar{2}1)$, and the base.

Hexagonal-hemimorphic Group. Examples: Zincite, wurtzite, iodyrite. These only differ from forms of the normal group in being hemimorphic on the vertical axis, the two ends of which axis show unlike faces. The forms are named as though they were normal, but are called "hemipyramids," etc.

Hexagonal-pyramidal Group. Examples: Apatite, pyromorphite. This group corresponds to the hexagonal pyramidal, having no vertical planes of symmetry, but the horizontal axial plane being a plane of symmetry. The new forms are the prism of the third order ($hki0$) and the pyramid of the third order ($hkil$). These forms only show the symmetry of the group when they are in combination.

The Rhombohedral or Trigonal Section. Vertical axis trigonal or ditrigonal.

Rhombohedral Group. Examples: Calcite, hematite. In this group of the trigonal section the vertical axis is ditrigonal, the lateral axes are binary, and the only set of planes of symmetry is the set of the planes of the vertical and intermediate axes. The symmetry is illustrated in Fig. 15, which shows the symmetry of the crystal axes as described above, and the position of the set of planes of symmetry lies midway between the axes $+a_1, -a_2$, etc., and passing through the second prism edges and the axis c. The group here

responds to the tetrahedral group of the isometric and the sphenoidal group of the tetragonal systems. The new forms are the *rhombohedron* (*h*0*hl*), ($10\bar{1}1$), and the *scalenohedron* (*hkīl*). All other forms are like those of the normal hexagonal group, and are so named. The *rhombohedron* is a solid bounded by six planes, which meet each end of the vertical axis in three equal dihedral angles, but so arranged that the dihedral edge at one end is opposite to a face at the other end. This is well shown in Fig. 15, where the faces ($10\bar{1}1$) are the rhombohedron, in combination with the second order prism ($11\bar{2}0$), and the base (0001). The basal section of the rhombohedron is an equilateral triangle, and it may be seen in Fig. 15 that the upper section

FIG. 15.

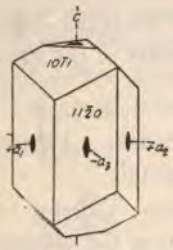


FIG. 16.

has a base of the triangle directed forward and an apex pointing backward, while the lower section would have the position reversed. This is the ditrigonal character noted above. The *scalenohedron* ($21\bar{3}1$) is shown in combination with the rhombohedron ($10\bar{1}1$) in Fig. 16. It has twelve faces, each a scalene triangle, from which character the name is derived. The angles of the pole edges of this form, meeting in the vertical axis, are

alternately more obtuse and more acute, so that there are two sets of three equal edges, meeting in the vertical axis.

Rhombohedral-Hemimorphic Group. Examples: Tourmaline, pyrargyrite. In this group the vertical axis is trigonal, the lateral axes are not axes of symmetry, and the only planes of symmetry are the vertical intermediate planes. The new forms are trigonal prisms and pyramids, and ditrigonal prisms and pyramids. Fig. 17 represents a crystal of tourmaline, and shows the second order prism $(11\bar{2}0)$, the trigonal prism $(10\bar{1}0)$, and, at the upper end, the trigonal pyramid marked $(02\bar{2}1)$; while at the lower end is seen the trigonal pyramid $(01\bar{1}\bar{1})$. The hemimorphic character

FIG. 17.

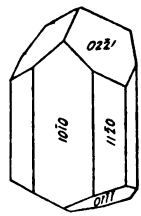


FIG. 18.

of tourmaline is shown by the development of pyroelectricity on heating. A crystal of this mineral, heated and allowed to cool, develops static electricity of opposite polarity at the two ends of the vertical axis.

Rhombohedral-Trapezohedral or *Trigonal-Trapezohedral Group.* Examples: Quartz, cinnabar. In this group the vertical axis is trigonal and the lateral axes are binary, but there are no planes of symmetry. Fig. *18 shows a crystal* of quartz, a mineral belonging

in this group. The forms represented are the unit prism ($10\bar{1}0$), the positive and negative rhombohedra of the first order, ($10\bar{1}1$) and ($01\bar{1}1$), the trigonal pyramid of the second order ($11\bar{2}1$), and the right-handed trigonal trapezohedron (5161) or (*hkil*). Other forms that may occur in the group are the trigonal prism of the second order ($11\bar{2}0$), the ditrigonal prism (*hki*0), and the base (0001). The vertical axis is trigonal, but appears unsymmetrically ditrigonal and *twisted*, and the minerals belonging in this group rotate the plane of polarization of light, traversing them in the direction of the vertical axis. The lateral axes are hemimorphic axes, and non-conductors in this group exhibit pyro-electric phenomena along these axes.

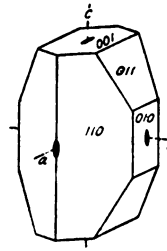
IV. THE ORTHORHOMBIC SYSTEM.

This system is characterized by unequal development in three directions at right angles to each other. The three directions of development are the three *crystal axes*. These axes are unequal, and are distinguished by selecting one as *vertical;* then of the other two, the longer is called the macro axis and the shorter the brachy axis. The relative lengths of these two horizontal axes is determined from a unit prism or a unit pyramid, the longer diagonal of the horizontal section of such a prism or pyramid being the macro axis, and the shorter the brachy axis. The macro axis is made unity in computing the axial ratio, and its position is made horizontal and right and left. The brachy and vertical axes are expressed in terms of this macro axis as unity. Three groups are distinguished: (*a*) the *normal*, in which the three directions of development, or

crystal axes, are binary axes, the three axial planes are planes of symmetry, and the crystal possesses a center of symmetry; (*b*) the *hemimorphic* group, in which only the hemimorphic axis is binary, and the two axial planes, including this axis, are planes of symmetry, but the crystal does not possess a center of symmetry; and (*c*) the *sphenoidal* group, in which, while the three crystal axes are binary, the crystal has no planes of symmetry and no center of symmetry.

The Normal Group. Examples: Sulphur, aragonite, barite, staurolite. Fig. 19 shows a crystal in the normal group of this system. The three crystal axes are lettered *a*, *b*, *c*, and are seen to be binary; the planes of these axes, taken two and two, are planes of symmetry; their intersection is the center of symmetry of the crystal.

FIG. 19.



The seven forms in this group are as follows:

1. Basal pinacoid, or base, (001).
2. Brachypinacoid, (010).
3. Macropinacoid, (100).
4. Unit prism (110), macroprisms (210), etc., brachyprisms (120), etc.
5. Brachydomes, (011), (012), (021), (032), etc.
6. Macrodomes, (101), (203), (102), etc.
7. Pyramids; unit pyramid, (111), and pyramids of the unit series as (112), (113), (223), etc.; macropyramids as (213), (212); brachypyramids (123), (122), etc.

The domes are horizontal prisms, and when both domes appear in the same crystal, they resemble pyra-

mids to some extent. Figure 20 shows a barite crystal with the following forms: Base (001), brachydome (011), and macrodome (102). Fig. 21 shows a sul-

FIG. 20.

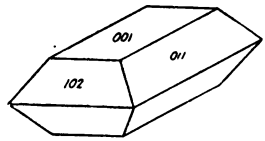
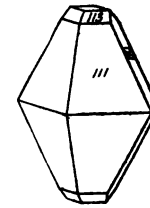


FIG. 21.



phur crystal with the combination of two pyramids of the unit series (111) and (113), and the brachydome (011), with the end of the pyramid truncated by the

FIG. 22.

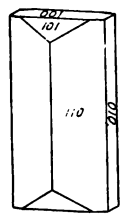
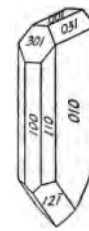


FIG. 23.



base (001). Figure 22 is a staurolite crystal, the combination being unit prism (110), macrodome (101), brachypinacoid (010), and base (001).

The hemimorphic group is illustrated in Fig. 23, which shows a crystal of calamine. In this prismatic zone the forms are unit prism (110), macropinacoid (100), bra-*chypinacoid (010)*; at the upper pole the forms are

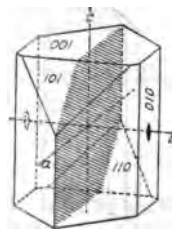
base (001), macrodome, (301) and brachydome (031); at the lower pole the termination is the brachypyramid $(12\bar{1})$. Calamine exhibits pyro-electricity, and when heated and allowed to cool it develops a negative charge on the upper pole (Fig. 23) and a positive charge on the lower pole.

The sphenoidal group is represented by such minerals as Epsom salt and zinc vitriol. In this group the pyramid is replaced by a sphenoid, analogous to the sphenoid of the tetragonal system.

V. MONOCLINIC SYSTEM.

In the monoclinic system the development is unequal along three axes, two of which (a and $\dot{c}$, Figure 24) are not at right angles with each other and the third (b) is at right angles to the plane of the other two. In the normal group, as well as in the clinohedral group, this plane of a and $\dot{c}$ is a plane of symmetry for the crystal (shown shaded in Figure 24) and is the only plane of symmetry the crystal possesses. The normal group is the only one that is common in minerals. Figure 24 represents such a normal group crystal. The axes are designated as the clino axis a, the ortho axis b (which in this group is binary), and the vertical axis $\dot{c}$ The seven forms of this group are as follows:

FIG. 24.



1. Basal pinacoid or base (001).
2. Clinopinacoid (010).
3. Orthopinacoid (100).
4. *Unit prism (110);* orthoprism (2\10), etc.; *clinorisms (120), etc.*

5. Clinodomes (012), (011), (021), etc.

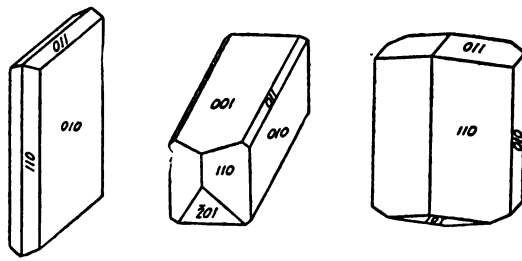
6. Orthodomes (102), (101), (203), etc.

7. Pyramids, of the unit series (111), (112), etc.; orthopyramids (213), (212), etc.; clinopyramids (123), (122), etc.

The pyramid is composed of two *hemipyramids*, each consisting of four like faces; and they are distinguished as the positive hemipyramid, lying in the acute angle between the crystal axes *a* and *c*, and the negative hemipyramid, in the obtuse angle. The orthodomes are also *hemidomes*, both composed of a parallel pair of faces, and are named as in the case of the pyramids. The clinodome and the prism are each composed of four like faces.

Figure 24 shows the combination of unit prism (110), clinopinacoid (010), basal pinacoid (001) and negative hemiorthodome (101). Figure 25 shows a gypsum

Fig. 25. Fig. 26. Fig. 27.



crystal, with the unit prism (110), the clinodome (011) and the clinopinacoid (010). Figure 26 is an orthoclase crystal (pseudomonoclinic), with the unit prism (110), the clinodome (011), the positive hemiortho-

dome (201), the clinopinacoid (010), and the base (001). Figure 27 is a hornblende crystal, with the unit prism (110), the clinodome (011), the positive hemiorthodome (101), and the clinopinacoid (010).

VI. TRICLINIC SYSTEM.

In this system the development is unequal in three directions, none of which are at right angles with each other. There are no binary axes, nor planes of symmetry in this system, but in the normal group there is a center of symmetry, and the forms therefore consist of parallel pairs of planes. Examples are: Axinite, the plagioclase feldspars (in fact, all feldspars), blue vitriol, rhodonite, etc. In this system the axes are named as in the orthorhombic system, one being chosen as the vertical axis, and, of the other two, the longer (determined from the unit prism or pyramid) is called the macroaxis and the other the brachyaxis. The forms are as follows:

1. Basal pinacoid or base (001).
2. Brachypinacoid (010).
3. Macropinacoid (100).
4. Unit prism (110), (1$\bar{1}$0); macroprisms (210), (2$\bar{1}$0), etc.; brachyprisms (120), (1$\bar{2}$0), etc.
5. Brachydomes (011), (0$\bar{1}$1), etc.
6. Macrodomes (101), ($\bar{1}$01), etc.
7. Pyramids of unit, macro- and brachy-series. Unit pyramid (111), ($\bar{1}$11), ($\bar{1}\bar{1}$1), (1$\bar{1}$1).

The triclinic character may be pronounced, as in Fig. 28, or the crystal may approach the monoclinic system, as in Fig. 29. Fig. 28 represents a crystal of *axinite, and shows the* combination of the two halves

of the unit prism (110) and ($1\bar{1}0$), with the macropinacoid (100) in the same zone, and the macrodome (201) with two faces of the unit pyramid ($1\bar{1}1$) and (111). A crystal of rhodonite is shown in Fig. 29,

Fig. 28.

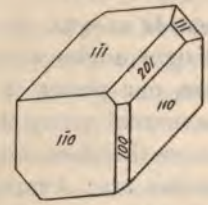
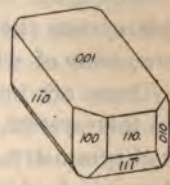


Fig. 29.



and this exhibits the combination of unit hemiprisms (110) and ($1\bar{1}0$), macropinacoid (100), brachypinacoid (010), base (001), unit tetartopyramid ($11\bar{1}$), and another tetartopyramid of the unit series ($2\bar{2}1$), this last the unlettered face below on the left.

It will be seen that in this system no form consists of more than two like planes, and hence all forms are of the nature of pinacoids; this normal group is hence often called the pinacoidal class.

CHAPTER III.

Auxiliary Apparatus and Manipulations in the Laboratory.

1. Pulverization.

Minerals usually require preparation for the blowpipe, as for solution, by pulverization. They may be broken in small pieces with a hammer, and then crushed in a diamond steel mortar (Fig. 30), in which *A*

Fig. 30.

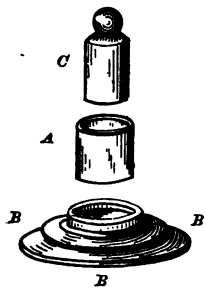
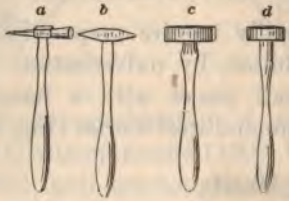


Fig. 31.

is a rim removable from bottom *B*. Pestle *C* fits the rim closely, and is driven by a heavy hammer into the rim upon the mineral. If repetition of this process does not soon prepare the mineral for the blowpipe, grinding in an *agate mortar* (Fig. 31) may be resorted to, as is *generally necessary* for solution.

Some minerals may be sufficiently reduced by wrapping them in strong, clean paper, and giving them a blow with a hammer, taking care not to contract any impurity. A small jeweler's steel hammer will answer for blowpiping, or the small hammers made especially for that purpose, those with wire handles being the most durable; but for trimming minerals and for geological and mining purposes, larger and variously-shaped steel

FIG. 32.



hammers have been adopted and may be obtained from the dealers.

Fig. 32, *a*, *b*, *c*, *d*, represent four different forms of such heavier hammers.

a. Freiberg pattern, one end flat, the other pointed.

b. Hutchinson's form, sharpened on both ends for trimming.

c. von Buch's form, one end flat, the other sharpened.

d. Hausmann's patterns, both ends sharpened.

Anvil. A square, flat piece of hardened steel answers well for an anvil.

Cutting pliers or *nippers* are useful for cutting off small fragments from a mineral specimen.

Magnets. A small steel bar-magnet shaped like a chisel, of hardened steel, or a horse-shoe magnet is

needed for recognizing magnetic metals. A small compass may also be used for this purpose.

A good magnifying glass or pocket lens is useful in examining minerals and metallic sublimations or deposits. The best kind of pocket lens is the acromatic triplet; next best is the doublet, which is very moderate in price.

2. SOLUTION AND CARBONIC DIOXIDE (CO_2) TEST.

In qualitative analysis small quantities are usually employed, therefore the solution of solids may be most conveniently conducted in a test-tube which can be readily heated over an alcohol lamp or a gas-burner.

FIG. 33.

FIG. 34.

Figs. 33 and 34 show two forms of racks with test-tubes. The latter has an attachment for filtration. If, in dissolving a substance, a colorless and inodorous gas is evolved, the latter may be carbonic dioxide (CO_2), and can be tested in the following simple manner: During evolution of gas in tube *a* (Fig. 35), the lip of the tube may be brought upon that of tube *b*, containing clear lime-water. As the gas from tube *a* flows into tube *b*, the water will become *milky* from formation of *calcium carbonate* $CaCO_3$.

FIG. 35.

Fig. 36 shows a metallic test-tube stand with test-tube;

Fig. 36.

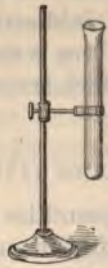


Fig. 37.

and Fig. 37 a test-tube holder of brass with wooden handle, both employed for heating purposes.

3. PRECIPITATION AND DECANTATION.

Many circumstances are to be considered in deciding whether a precipitate will be produced with a given reagent, such as temperature, concentration, or dilution; the presence of some disturbing agent, or absence of a substance which might favor the action by the influence of some affinity. Therefore a single trial should not satisfy the student; the experiment should be varied especially if resort be had to *heat*, agitation, and time.

Fig. 38.

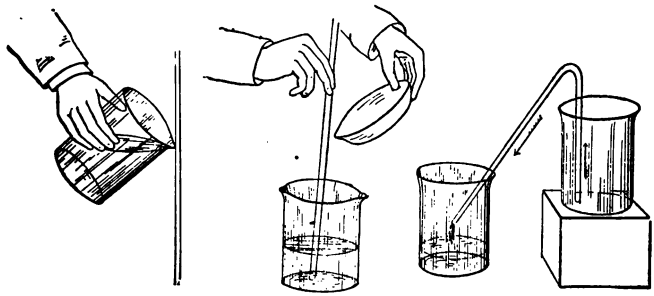
The beaker (Fig. 38), made of Bohemian glass of uniform thickness, and a test-tube, serve best for precipitation, the liquid in the former being agitated

by a glass rod. When precipitation is complete, the subsidence of the precipitate often allows the mother liquor to be removed by *decantation.*

Precipitations of barium, for example, may be readily separated and washed without filtration. To avoid spilling in decanting, a portion of the lip of the vessel should be smeared internally and externally with tallow, and then this portion brought against a glass rod held obliquely, when the liquid will flow gently down the rod without danger of waste.

Figs. 39 and 40 show how a stream of liquid flowing

FIG. 39. FIG. 40. FIG. 41.



from a beaker or basin (porcelain dish) should be guided by a glass rod placed against the point whence the stream emerges. If the vessel be too large or too full to handle with convenience, the wash-water may be drawn off by a syphon, as shown in miniature in Fig. 41. A siphon is a tube of glass, metal, gutta-percha, or India-rubber, bent in the form of a V or U, filled with water, and inverted; one end immersed in the wash-water *and the other* allowed to hang over the side of the

vessel; so long as the outer orifice of the instrument is below the level of the liquid in the vessel, so long will that liquid flow from within outwards until the vessel be empty.

Fig. 42.

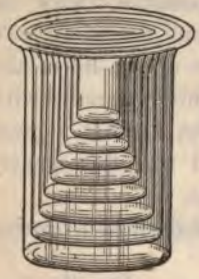


Fig. 42 represents a set (nest) of beakers without spout, all of uniformly thin glass, bearing well the heating of liquids which they contain, in a sand-bath or over a naked flame.

Fig. 43 shows a set of beakers with spouts.

Fig. 44 exhibits German flasks of white glass with long necks and flat bottoms, in

Fig. 43.

Fig. 44.

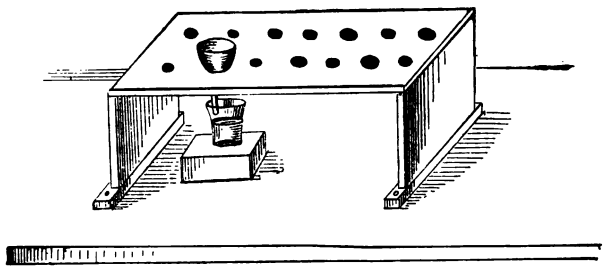
which liquids may be boiled, or minerals dissolved in acids, over a naked flame.

4. FILTRATION.

Precipitates are generally separated from the mother-liquor by filtration, as shown in Fig. 45, through paper

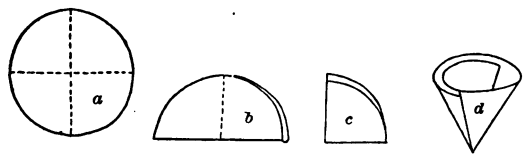
expressly prepared for the purpose (Swedish is best, but a cheaper article answers for qualitative analysis). The paper, as seen in Fig. 46, is cut in a circular form,

FIG. 45.



a, then folded in the shape of a quadrant, *b* and *c*, the pointed part finally placed deep in a glass funnel, and one of the folds, *d*, spread back so that the paper com-

FIG. 46.



pletely lines the glass, though it must not quite reach the top. When fitted, the paper is moistened by a jet of water to cause it to adhere to the glass. If a precipitate subsides, the supernatant liquid should first be run through the filter by itself, to accelerate filtration.

Figs. 47 and 48 show additional forms of filtering

stands. The latter, being made of iron, can also be used as a retort-stand in distilations.

FIG. 47.

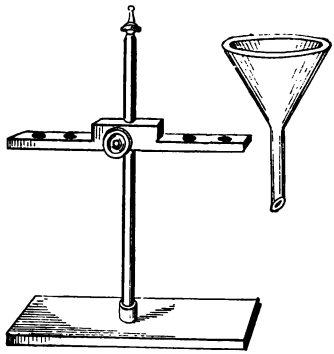


FIG. 48.

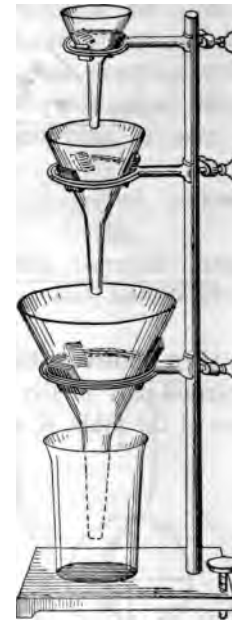
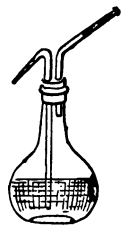


FIG. 49.

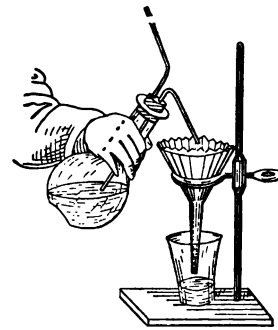


Washing Precipitates.

Fig 49 represents the ordinary wash-bottle for washing precipitates from the side of a filter by a jet of water, by compression of the air in the bottle, caused by blowing (see Fig 50). To test whether the washing has been complete, a drop of the filtrate coming

from the funnel is evaporated on a platinum spatula; if no solid residue remains behind, the operation should be discontinued.

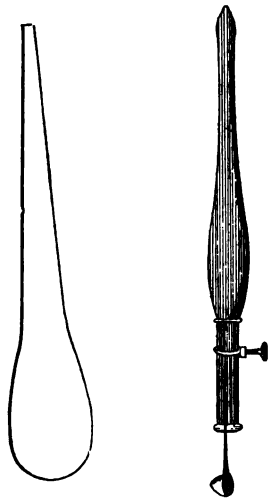
Fig. 50.



In Fig. 51 a platinum spatula is shown in its natural size, and Fig. 52 shows a convenient wooden holder for spatula, wire, and spoon for heating operations.

Fig. 53 is a holder for platinum spoon and wire,

Fig. 51. Fig. 52. Fig. 53.



with screw fastening. The handle is hollow to contain *wire and spoon,* screw cap.

5. EVAPORATION.

After filtration the mother-liquor becomes so much increased by washing as often to require concentration before being treated for substances yet in solution. Evaporation may be conducted in a porcelain dish, either over a lamp or on the sand-bath. Boiling should be avoided, and for this purpose the dish can be securely placed upon a water-bath of copper (about five inches in diameter), shown in Fig. 54, which is provided with rings to receive dishes of different sizes, and is supported by a tripod or a retort-stand. Being

FIG. 54. FIG. 55. FIG. 56.

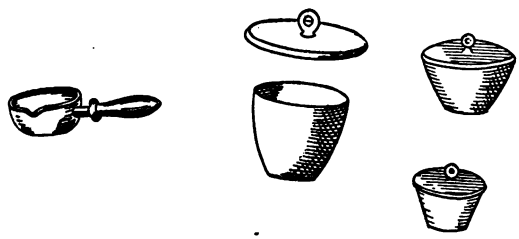
partly filled with water, it is heated by a small alcohol lamp or a gas burner. To prevent dust from falling into the dish, it may be covered with filter-paper, supported by a glass rod, or closely bent over the edge of the dish. When the dish is nearly full, the substance may often be prevented from running over the margin by slightly touching the latter with tallow. In evap-

orating to dryness, the process is facilitated by stirring. Fig. 55 shows a simple tripod of iron, and Fig. 56 is a tripod with chimney, by Bunsen, to be used in connection with his gas-burner. A square piece of iron-wire gauze is frequently put under dishes, beakers, or flasks, heated on these tripods, or iron retort-stands, to moderate the effect of the direct flame of a gas-burner.

6. PORCELAIN DISHES AND CRUCIBLES.

Open dishes, which will bear heat without cracking, are necessary implements in the laboratory for conducting the evaporation of liquids. The best evaporating dishes are those made of Berlin porcelain, glazed both inside and out, with a small lip projecting beyond the rim.

FIG. 57. FIG. 58.



The dishes of Meissen porcelain are not glazed on the outside, and are not so durable, but much cheaper than those of Berlin manufacture. Evaporating dishes are made of all diameters from 3 cm. to 15 cm.

A deep porcelain dish, provided with a handle, called a casserole, is seen in Fig. 57.

Very thin, highly glazed porcelain crucibles, with glazed covers (*Fig.* 58), are indispensable implements

to the chemist. For most purposes the best sizes are those between 3 cm. and 5 cm. in diameter. Porcelain crucibles are supported over a lamp on an iron-wire triangle. They must always be gradually heated, and never come suddenly in contact with any cold substance while they are hot.

7. PLATINUM APPARATUS: CRUCIBLES, DISHES, OR CAPSULES.

Platinum does not oxidize in the air at any temperature, nor is it attacked by any of the common acids used separately. This comparative inertness as a chemical agent, taken in connection with its infusibility, renders platinum an extremely useful metal to the chemist.

It is employed in the laboratory for crucibles, evaporating dishes, stills, boats for igniting precipitates, spatulæ, forceps, wire, blow-pipe tips, etc., and in the shape of perforated cones for use with the filter-pump.

FIG. 59.

FIG. 60.

When a filter-pump is at hand, other insoluble precipitates collected on an ordinary paper filter may be quickly washed when placed in such a cone, and the latter in a glass funnel.

Fig. 59 represents a platinum crucible with a capsule-

shaped lid, convenient for the incineration of filters, etc. Fig. 60 shows a platinum evaporating dish with lip.

8. CRUCIBLE TONGS.

The following three convenient forms of tongs for removing hot crucibles from the fire are generally found in laboratories.

FIG. 61.

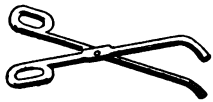


FIG. 62.

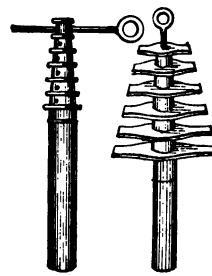
Fig. 61 represents plain tongs of malleable iron. Fig. 62 shows tongs with a double curve. Fig. 63 exhibits somewhat expensive, but durable, crucible tongs, made of German silver with platinum points attached.

FIG. 63.

9. CORKS.

For chemical purposes these should be made of soft cork-wood cut across the grain to prevent forming continuous channels for the passage of gases or liquids. Pierced corks are used to form joints with retorts, gas-bottles, and other chemical apparatus. Boring holes through corks to receive glass tubes, necks of retorts, etc., may be done with a round file (rat-tail), or better, by a hollow cylinder of sheet brass sharpened *at one end*. Fig. 64 represents a set of cyl-

FIG. 64.



inders of graduated sizes, slipping one within the other into a very compact form. A stout wire of the same length as the cylinders accompanies the set, which serves a double purpose: passed tranversely through two holes in the cap which terminates each cylinder, it gives the hand a better grasp of the tool while penetrating the cork; and when the hole is made, the wire thrust through the opening in the top of the cap expels the little cylinder of cork which else would remain in the cutting cylinder of brass.

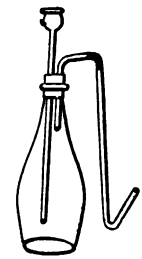
Rubber stoppers of flexible unvulcanized caoutchouc,

FIG. 65.

cast in moulds of various sizes, and provided with 1, 2, and 3 holes, are now employed in laboratories instead of cork stoppers. Fig. 65 represents different samples. These sell for about $3 per pound. Caoutchouc stoppers of good quality are much more durable than corks, and are in every respect to be preferred. Caoutchouc

stoppers can be bored like corks by means of the cutters above mentioned, moistened with Na(OH), and glass tubes can be fitted into the holes thus made with a tightness unattainable with corks. Stoppers can be bought provided with all the necessary holes of various sizes.

Fig. 66.



In Fig. 66 is seen a gas-bottle, fitted with perforated stopper, funnel-tube, and jointed delivery-tube.

10. SAND-BATH, WIRE GAUZE, TRIANGULAR SUPPORTS FOR CRUCIBLES.

As a general rule it is not best to apply the direct flame to glass or porcelain vessels; hence a piece of wire gauze is stretched loosely over the largest ring of an iron stand, and bent downward a little for the reception of round-bottomed vessels. On this gauze, flasks, retorts, and porcelain dishes are usually supported. In cases requiring a very gradual and equable heat the wire gauze is replaced by a small sand-bath, *i. e.*, a shallow sheet-iron pan filled with dry sand (Fig. 67). *Crucibles* or *dishes* of *porcelain* or *platinum*, too small for the smallest ring belonging to the stand, are conveniently supported on an equilateral triangle made of three pieces of soft iron, copper, or platinum wire, twisted together at the apexes; this triangle is laid on one of the rings of the stand. An iron tripod (Fig. 55) may be often used instead of a stand, but it is not so

Fig. 67.

generally useful because of the difficulty of adjusting it to various heights; with a sufficiency of wooden blocks wherewith to raise the lamp or the tripod as occasion may require, it may be made available. The whole apparatus for ignition, in its various arrangements, is plainly shown in the following illustrations.

Fig. 68 shows an ordinary iron stand with two rings; on the upper one is placed a wire triangle, and on the lower one a piece of wire gauze.

FIG. 68.

FIG. 69.

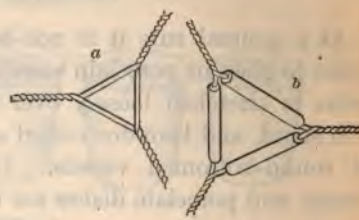


Fig. 69 exhibits two such wire triangles, *a* and *b*; the latter, *b*, is covered with tobacco-pipe stems.

Fig. 70 is a support of iron with fork for holding a Bunsen burner, with rubber gas-tube attached. The burner with chimney heats a crucible, resting on a wire triangle.

In Fig. 71 is seen the burner by itself with a star screwed on for the support of a chimney and an arrangement to slide on the fork of the iron stand.

FIG. 70.

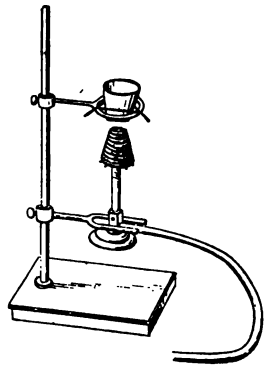


FIG. 71.

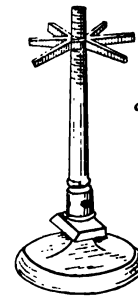


Fig. 72 shows a burner with a support screwed on for holding small porcelain dishes.

FIG. 72.

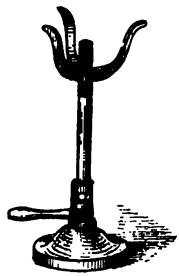
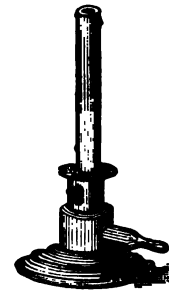


FIG. 73.



An ordinary plain Bunsen gas-burner is seen in Fig. 73.

11. FLETCHER'S BURNERS.

Fig. 74 represents Fletcher's Blast-Bunsen for high temperatures. This is a Bunsen combined with a powerful blowpipe, and is one of the most generally useful arrangements known in the chemical laboratory. The blowpipe flame obtained with the blast tube, when confined by the loose cap *b*, is compact and extremely powerful, owing to the fact that the air mixture is partially made before the blast begins to act. When the object to be heated is fragile it can be warmed by

FIG. 74.

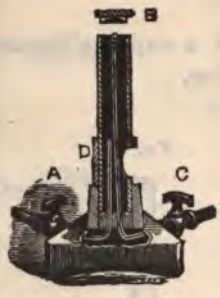


FIG. 75.

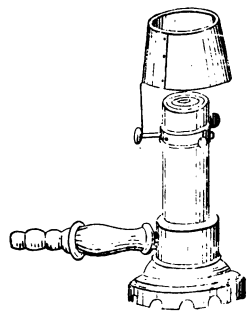
the Bunsen flame and the blast slowly turned on by the tap *c*. The convenience of having a powerful flame at command under an ordinary retort-stand without the necessity of readjusting the height or position will be fully appreciated.

Fig. 75 represents the Fletcher-Plattner Blowpipe Furnace, for capsules, or crucibles, $\frac{3}{4}$ in. diameter. This is made of Fletcher's patent non-conductor, which

does not require renewing, and does not require the objectionable wire support of Plattner's pattern, which generally fails at the most critical moment. This pattern, like that of Plattner, has the hole for the blowpipe flame at the side; but if the hole is at the bottom, and an upright blowpipe is used, the improvement is very great. With the blast Bunsen (as shown in Fig. 74) and a good foot blower, 100 grains of cast iron can be perfectly fused in two minutes; the temperatures being, at the same time, under the most perfect control.

In Fig. 76 is seen Erlenmeyer's Argand Burner for

FIG. 76.



heating purposes. It has met with much favor among chemists for the intense, steady heat it gives. It may be used for simple fusions of silicates nearly as well as a blast lamp.

12. FOOT BLOWERS.

Fig. 77 is a simple, compact, and powerful arrangement. The step for the foot is very low, and enables the blower to be used with ease whether the operator is

standing or seated. The pressure is perfectly steady and equal. If the rubber disk is distended until forced against the net, the pressure can be increased to almost any extent desired. It will give, if required, a heavy

FIG. 77.

and continuous blast through a pipe of $\frac{1}{4}$ inch clear bore.

A great advantage is obtained in blowpipe work by attaching a stop-cock to the air-pipe, thereby controlling the blast as well as with the mouth. With the blast Bunsen lamp connected with such a blower, small quantities of cast-iron can be perfectly fused in a few minutes.

13. BENDING AND CLOSING GLASS TUBES.

Small-bore tubing can generally be worked in the flame of a common gas or spirit-lamp, or over an ordinary gas-burner; for larger tubes the blast-lamp is necessary (see Figs. 74 and 75). Glass tubing must not be introduced suddenly into the hottest part of the flame, or laid at once upon a cold surface. Gradual

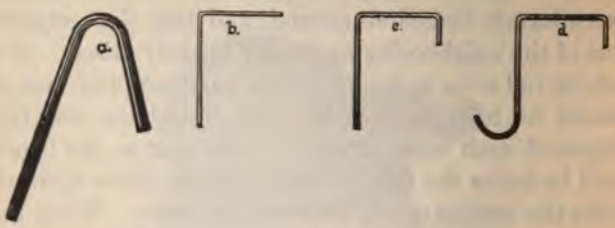
heating and gradual cooling are alike necessary, and more so, the thicker the glass is. In heating a tube, whether for bending, drawing-out, or closing, the tube must be constantly turned between the fingers, and also moved a little to the right and left in order that it may be uniformly heated all around, and that the temperature of the neighboring parts may be duly raised. If a tube or rod is to be heated at any part except an end, it should be held between the thumb and the first two fingers of each hand in such a manner that the hands shall be below the tube or rod, with the palms upward, while the lamp-flame is between the hands. When the end of a tube or rod is to be heated, it is best to begin by warming the tube or rod about 2 cm. from the end, and from thence proceed slowly to the end.

In bending tubing to make gas delivery-tubes and the like, attention should be paid to the following points: 1st, the glass should be equally hot on all sides; 2d, it should not be twisted, pulled out, or pushed together, during the heating; 3d, the bore of the tube at the bend should be kept round and not altered in size; 4th, if two or more bends be made in the same piece of tubing (Fig. 78), *c* and *d*, they should all be in the same plane, so that the finished tube will lie flat upon the level table.

When a tube or rod is to be bent or drawn close at its extremity, a temporary handle may be attached to it by softening the end of the tube or rod, and pressing against the soft glass a fragment of a glass tube, which will adhere strongly to the softened end. The handle may subsequently be removed by a slight blow, or by the *aid of a file.*

If a considerable bend is to be made, so that the angle between the arms will be very acute, as in a siphon, for example at *a*, Fig. 78, the curvature cannot

FIG. 78.

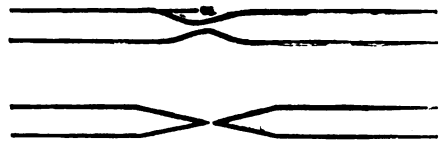


be well produced at one place in the tube, but should be made by heating, progressively, several centimeters of the tube, and bending continuously from one end of the heated portion to the other. The ordinary fish-tail gas burner for illuminating serves admirably for heating tubes for bending as above described. Small and thick tubes may be bent more sharply than large or thin tubes. In order to draw a glass tube down to a finer bore, it is simply necessary to thoroughly soften, on all sides, one or two centimeters' length of the tube, and then, taking the glass from the flame, to pull the tube by a cautious movement of the hands. The larger the heated portion of the glass, the longer will be the tube thus formed. Its length and fineness also increase with the rapidity of motion of the hands.

To obtain a tube closed at one end, it is best to take a piece of tubing open at both ends, and long enough to make two closed tubes. In the middle of the tube a ring of glass, as narrow as possible, must be made thor-

oughly soft. The hands are then separated a little to cause a contraction in diameter at the hot and soft part. The point of the flame must now be directed, not upon the narrowest part of the tube, but upon what is to be the bottom of the closed tube. This point is indicated by the line *a* in Fig. 79. By drawing with the right

FIG. 79.



hand, the narrow part of the tube is attenuated, and finally melted off, leaving both halves of the original tube closed at one end, but not of the same form; the right-hand half is drawn out into a long point, the other is more roundly closed. It is not possible to close handsomely the two pieces at once. The tube is seldom perfectly finished by the operation; a superfluous knob of glass generally remaining upon the end. If small, it may be got rid of by heating the whole end of the tube, and blowing moderately with the mouth into the open end. The knob being hotter, and therefore softer than any other part, yields to the pressure from within, spreads out, and disappears. If the knob is large it may be drawn off by sticking to it a fragment of a tube, and then softening the glass above the junction. The same process may be applied to the too pointed end of the right-hand half of the original tube, or to any misshapen result of an unsuccessful attempt to close a tube, or to any bit *of tube which is* too short to make two closed

tubes. When the closed end of a tube is too thin, it may be strengthened by keeping the whole end at a red heat for two or three minutes, turning the tube constantly between the fingers. It may be said in general of all the preceding operations before the lamp, that *success depends on keeping the tube to be heated in constant rotation, in order to secure a uniform temperature on all sides of the tube.*

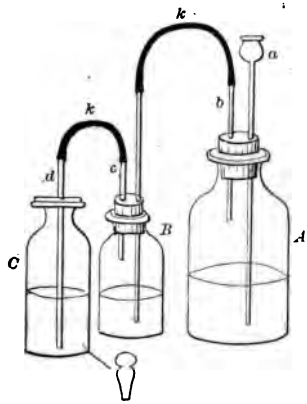
CHAPTER IV.

Reagents Most Frequently required for Analysis in the Wet Way.

1. HYDRIC SULPHIDE, SULPHURETTED HYDROGEN = H_2S.

A colorless gas which should be evolved at the moment of using it. For this purpose monosulphide of iron, or ferrous sulphide FeS, in fragments of the size

Fig. 80.



of a pea, is placed in a bottle, *A*, Fig. 80, and covered with pure water. Through funnel tube, *a*, concentrated sulphuric acid is added by degrees, and the evolved gas

can escape only through *b* into flask *B*, which should contain some water for washing the gas. From *B* the gas is forced through tubes *c* and *d* (connected by India-rubber tubes, *k*) into flask *C*, which contains the solution to be treated.

A very handy apparatus for generating H_2S, in small quantities, is Babo's, mounted on a stand with rubber connection, as shown in Fig. 81.

FIG. 81.

FIG. 82.

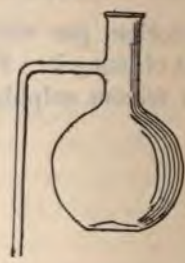


Fig. 82 represents a gas bulb for passing sulphide of hydrogen (or chlorine gas) into liquids in test-tubes. After being charged the orifice on the top is closed with a cork.

2. SULPHIDE OF AMMONIA $(NH_4)_2S$.

Should be often freshly prepared, and preserved in well-stoppered bottles. It is obtained by conducting sulphydric acid gas = H_2S, into aqueous ammonia until the latter absorbs no more of the gas. The apparatus, Fig. 82, will serve for the purpose by the addition of a loose stopper to flask *C*, in which the aqueous ammonia is to be placed.

3. HYDROFLUORIC ACID HF.

Pure hydrofluoric acid may be purchased from dealers in chemicals.

In experimenting with this acid, especially in a gaseous form, great care is necessary, since the fumes, when inhaled, may produce dangerous effects.

To obtain it in more or less concentrated liquid form, a small retort of platinum or lead is used, on which, during the operation, a helm is luted. The retort is previously charged with one part of finely powdered fluorspar and 2 parts of concentrated sulphuric acid. After the charge is thoroughly mixed by a platinum spatula, heat is applied. If a dilute acid is desired, the receiver, consisting of a platinum dish, must contain some water, and be well cooled from without with ice or a freezing mixture.

A glass plate may now be covered with etching-ground (consisting of 6 parts of gum mastic, 1 part asphaltum, and 1 part of wax), and parts of it removed with an etching needle (drawing). The glass plate thus prepared may now be acted upon (etched) either by the gaseous or liquid acid; in the former case the drawing is lustrous (like the original glass), while in the latter the drawing appears dull or opaque. The etching-ground can be removed with oil of turpentine.

For testing minerals for HF with sulphuric acid, it is well to employ a platinum crucible, the cover of which has an opening in the middle upon which a piece of glass is placed; the crucible and contents may then be heated over a lamp. Many silicates containing fluorine, like topaz, give off no trace of fluorine in this way. *To prove its* presence 2 grams of the powdered

mineral are mixed with caustic potash and a little liquid silicate of potash (water glass), and the whole fused in a silver crucible for a quarter of an hour. The cold mass is then dissolved in water, the silica precipitated with a solution of sal-ammoniac, and filtered off. To the filtrate, acidulated with HCl, we add a solution of chloride of calcium, and precipitate with ammonia the fluoride of calcium. This, after being well dried, is further tested with sulphuric acid.

4. WET REAGENTS GENERALLY. WATER = H_2O.

In all analytical operations, for solutions of other reagents, etc., pure distilled water ought to be used or rain water collected in the open air may, in many cases, be substituted for distilled water.

Hydrochloric or Muriatic acid = HCl, both concentrated and diluted.

Nitric acid = HNO_3, both concentrated and diluted.

Aqua regia, nitro-muriatic acid, is a mixture of 2-4 parts of concentrated hydrochloric and 1 part of nitric acid. It should be mixed when required.

Sulphuric acid (oil of vitriol) = H_2SO_4, concentrated and diluted with water.*

Common phosphoric acid or (Ortho-phosphoric acid) = H_3PO_4. It can easily be prepared from phosphorus and (diluted) nitric acid.

Ammonia. Ammonic hydrate. Liquor ammoniæ, = NH_4OH.

Carbonate of Ammonia. Ammonic carbonate $(NH_4)_2CO_3$.

* In diluting "oil of vitriol" the acid must gradually, and little at a time, be poured into water; the reverse action may prove very dangerous.

Chloride of ammonia. Ammonic chloride. Sal-ammoniac = NH_4Cl.

Phosphate of soda. Sodic phosphate = Na_2HPO_4, $12H_2O$.

The commercial salt ought to be purified by solution in water and recrystallized by evaporation.

Nitrate of baryta, Baric nitrate = $Ba(NO_3)_2$.

Nitrate of silver, Lunar caustic, Argentic nitrate = $AgNO_3$.

Chloride of platinum = $PtCl_4$.

Place a fragment of platinum in a little aqua regia and set the vessel aside in a warm place, adding more acid from time to time, if necessary; a solution of perchloride of platinum = $PtCl_4$ results. Evaporate the solution to remove excess of acid, and complete the desiccation (drying) over a water-bath. Dissolve the residue in 10 parts of water as a reagent for detecting potassa in the presence of soda and lithia. It precipitates, however, salts of ammonia also.

Molybdate of ammonia = $(NH_4)_2MoO_4$. It is obtained by dissolving molybdic oxide MoO_3 in ammonia, filtering, evaporating and crystallizing.

To prepare the molybdenum solution used for precipitating phosphoric and arsenic acids, 100 grams of molybdenum trioxide are dissolved in 50 c.c. ordinary aqueous ammonia and 80 c.c. water, and the solution is then poured into a mixture of 500 c.c. nitric acid and 300 c.c. water; if a precipitate forms it must be filtered off.

Oxalate of ammonium = $(NH_4)_2C_2O_4,2H_2O$, can be synthetically prepared as follows, or may be obtained already prepared:

To a nearly boiling solution of one part of oxalic acid in about 8 of water, add carbonate of ammonium until the liquid is neutral to test-papers, filter while hot, and set aside for the formation of crystals. The mother liquors are further evaporated to crystallization. To obtain the pure salt it ought to be re-crystallized a second time. Dissolve 1 part of the pure salt in 30 parts of water.

Caustic potash or *Potassic hydrate* = KOH. Dissolve some sticks of potassa in water, and separate the clear solution from the sediment (SiO_2, Al_2O_3) by decantation.

Chloride of barium. Baric chloride = $BaCl_2$.

5. PREPARATION OF TEST-PAPERS.

1. *Blue Litmus Paper.*—Digest 1 part of litmus of commerce with 6 parts of water, and filter the solution; divide the intensely blue filtrate into two equal parts; saturate the free alkali in the one part by repeatedly stirring with a glass rod dipped in very dilute sulphuric acid, until the color of the fluid just appears red; add now the other part of the blue filtrate, pour the whole fluid into a dish, and draw strips of filter-paper through it; suspend these slips over threads, and leave them to dry. The color of the litmus paper must be uniform, and neither too light nor too dark.

2. *Reddened Litmus Paper.*—Stir blue solution of litmus with a glass rod dipped into dilute sulphuric acid, and repeat this process until the fluid has just turned distinctly red. Steep slips of paper in the solution and dry them as in 1.

3. *Turmeric Paper.*—Digest and heat 1 part of bruised turmeric root (or turmeric powder) with 4 parts of

)l and 2 of water, filter the tincture obtained, and slips of fine paper in the filtrate. The dried slips exhibit a fine yellow tint. Test paper must be in closed boxes, or in black bottles, away from and fumes.

CHAPTER V.

Blowpipe Analysis and Apparatus.

1. The Mouth Blowpipe.

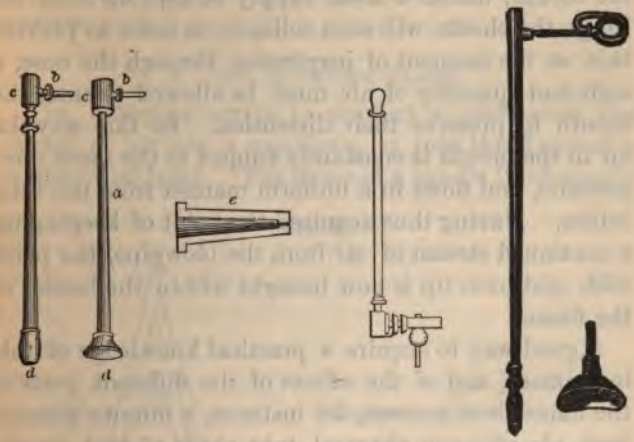
This simple instrument of very ancient origin is a most convenient apparatus for heating, melting, volatilizing, oxidizing, or reducing mineral substances on a small scale. By blowing air into the interior of a flame, always a burning gas, *i. e.*, carbo-hydrogen, the combustion is of course rendered more complete and rapid, and hence the intensity of heat increased. It is of the greatest service to the chemist, mineralogist, and practical miner for the recognition of minerals and ores, and the detection of certain chemical constituents, such as metals and others.

The improved chemical blowpipe, Fig. 83, consists of a chamber, *c*, near the extremity of the instrument, which collects the condensed moisture; this is connected with two tubes with ground joints. To the longer one, *a*, is attached a mouth-piece for blowing, of different shapes, and made of hard rubber, horn, or ivory. The shorter exit-tube is generally furnished with a movable tip, *e*, made of solid platinum, which may be easily cleansed from soot collecting upon it by simply heating it in the flame of a spirit-lamp.

The best shape of the tip is that represented in its

natural size, Fig. 83, at *e;* it always produces a well-defined and conical flame. Fig. 84 represents Plattner's

FIG. 83. FIG. 84. FIG. 85.



blowpipe, with gas-blast attachment, and marked regulating stopcock. The above attachment is sold separate from the rest of the blowpipe, and can be fastened to other blowpipes.

Fig. 85 is Fletcher's hot-blast chemical blowpipe—a pattern of the ordinary chemical blowpipe with the patent hot-blast arrangement.

2. BLOWING WITH THE BLOWPIPE.

To keep up a continuous current of air through the blowpipe is at first a difficult task. This, however, is easily overcome by attending to the following directions: Closing the mouth, keep the cheeks distended with air during a *number of inspirations* and expirations per-

formed through the nostrils. Next attempt the same with the ivory mouth-piece of the blowpipe between the lips. Now, as this provides an exit for the air in the mouth, unless a fresh supply be kept up from the lungs, the cheeks will soon collapse; in order to prevent this, at the moment of inspiration through the nose, a sufficient quantity of air must be allowed to enter the mouth to preserve their distension. In this way the air in the mouth is constantly subject to the same compression, and flows in a uniform manner from the little orifice. Having thus acquired the habit of keeping up a continued stream of air from the blowpipe, the point with platinum tip is now brought within the border of the flame.

A good way to acquire a practical knowledge of this instrument, and of the effects of the different parts of the flame, is to convert, for instance, a minute piece of lead, placed upon charcoal, into oxide of lead, by exposing it to the outer flame, and afterwards to reduce this oxide, *i. e.*, to restore it to its original metallic state by heating it in the inner flame. The reduction is much facilitated by an admixture of soda or cyanide of potassium.

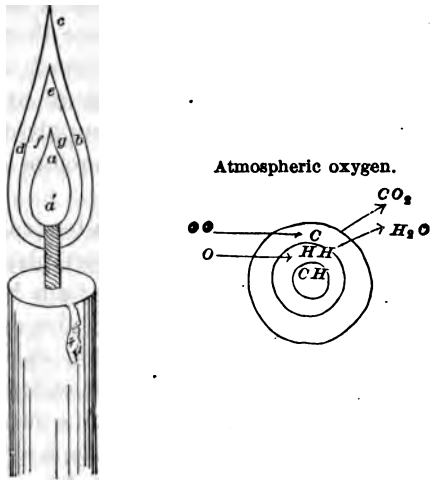
Flaming, *Flattern* (Germ.); *Flamber* (French).—In many cases when a transparent bead is intermittingly heated in the flame, or is repeatedly taken out of the flame, peculiar effects are obtained. This operation has obtained the name of "flaming." Clear beads frequently become opaque, milk-white, or even colored. This depends upon the fact that certain compounds which dissolve at a high temperature separate out on being heated to a somewhat lower temperature, appear-

ing as peculiar crystals, which are sufficiently well formed in most cases to be visible under the microscope when the bead has been flattened whilst hot, or when it has been dissolved in dilute acid so as to isolate the crystals.

3. THE BLOWPIPE FLAME.

The blowpipe serves to conduct a continuous fine current of air into a gas-flame, or into the flame of a candle or oil lamp. The flame of a candle (and equally

FIG. 86.



so that of a gas or of an oil lamp), burning under ordinary circumstances, is seen to consist of three distinct parts, as shown in Fig. 86, viz., 1st, a dark nucleus in the centre, *a*, *a'*; 2d, a luminous cone surrounding this nucleus, *e*, *f*, *g*; *and* 3d, a feebly luminous mantle en-

circling the whole flame, *b*, *c*, *d*. The dark *nucleus* is formed by the gases which the heat evolves from the tallow or oil, and which cannot burn here for want of oxygen. In the *luminous cone* these gases come in contact with a certain amount of air, insufficient for their complete combustion. In this part, therefore, it is principally the hydrogen of the hydrocarbons evolved which burns, while the carbon separates in a state of intense ignition, thus imparting to the flame the highly luminous appearance observed. In the outer coat the access of air is no longer limited, and all the gases not yet burned are consumed here. This part of the flame is the hottest; oxidizable bodies oxidize therefore with the greatest possible rapidity when placed in it, since all the conditions of oxidation are here united, viz., high temperature and an unlimited supply of oxygen. This outer part of the flame is therefore called the *oxidizing flame*.

On the other hand, oxides having a tendency to yield up their oxygen, suffer *reduction* when placed within the *luminous* part of the flame, the oxygen being withdrawn from them by the carbon and the still unconsumed hydrocarbons present in this sphere. The luminous part of the flame is therefore called the *reducing flame*. The effect of blowing a fine current of air across the flame is, first, to alter the shape of the latter, which, from tending upward, is now driven sideways in the direction of the blast, and at the same time lengthened and narrowed; and, in the second place, to extend the sphere of combustion from the outer to the inner part. As the latter circumstance causes an extraordinary increase of the heat of the flame, and the

former a concentration of the heat within narrower limits, it is easy to understand the exceedingly energetic action of the blowpipe flame. The way of holding the blowpipe, and the nature of the current, will always depend upon the precise object in view, viz., whether the operator wants a *reducing*, or an *oxidizing* flame. The easiest way of producing efficient flames of both kinds is by means of coal-gas delivered from a tube. The task of keeping the blowpipe steadily in the proper position may be greatly facilitated by resting that instrument firmly upon some movable metallic support, such as, for instance, Bunsen's gas-lamp, Fig. 97.

Fig. 87 shows the flame for reducing, and Fig. 88 the flame for oxidizing.

The reducing flame is produced by keeping the tip of the blowpipe just on the border of a tolerably strong gas-flame, and driving a moderate blast across it. The resulting mixture of the air with the gas is imperfect, and there remains between the inner bluish part of the flame, and the outer barely visible part, a luminous and reducing zone of which the hottest point lies somewhat beyond the apex of the inner cone. To effect reduction with this flame the assay is held at *d*, Fig. 87; if held at *a*, the flame is oxidizing.

To produce the *oxidizing* flame, the gas is lowered, the tip of the blowpipe pushed a little further into the flame, and the strength of the current somewhat increased. This serves to effect an intimate mixture of the air and gas, and an inner pointed bluish cone, slightly luminous towards the apex, is formed and surrounded by a *thin, pointed*, light bluish, barely visible

mantle. The hottest part of the flame is at the apex of the inner cone, which is reducing. Bodies fusible with difficulty are exposed to this part to effect their fusion;

FIG. 87.

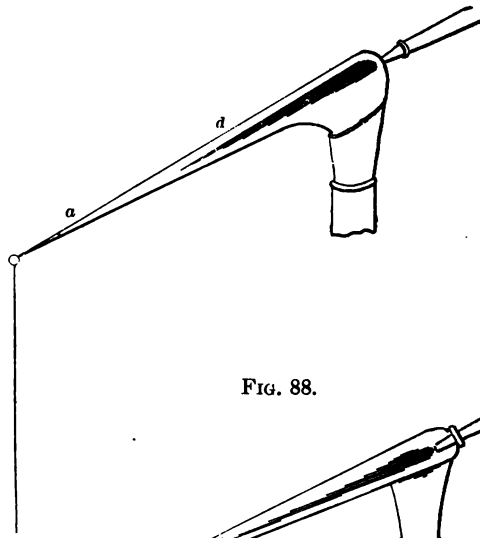
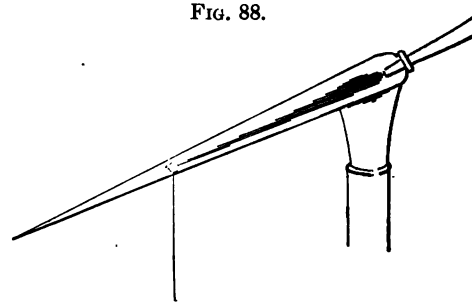


FIG. 88.



but bodies to be oxidized are held a little beyond the apex, that there may be no want of air for their combustion.

4. SUPPORTS FOR THE ASSAY.

I. *Charcoal*, well burnt and of uniform texture, forms

an ordinary support for assays. The piece should be about six inches long, one end wrapped in paper, and in the other a small cavity must be cut, half the size of

FIG. 89.

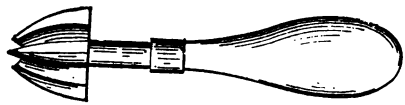
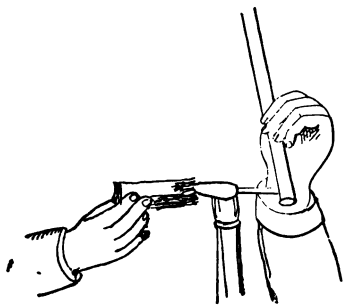


FIG. 90.

FIG. 91.

a pea, either with the point of a knife, or by means of charcoal borers, Figs. 89, 90 and 91. The heating of

FIG. 92.



an assay on charcoal in the blowpipe flame is illustrated *in Fig. 92.*

II. *Porcelain Supports.*—Foster and Fletcher in England use pieces of glazed porcelain made of the size and shape of charcoal supports. On the end of these porcelain plates are cavities into which small pieces of charcoal are fitted, upon the surface of which the blowpipe assay is placed. The whole surface of the porcelain is blackened over a lamp. This coat of soot takes up and exhibits films or coatings as well as charcoal. Similar to the porcelain supports are the plaster of Paris tablets, made by casting thin plaster upon an oiled glass plate, ruling it into $1\frac{1}{2}\times4$ inch spaces, and breaking apart when set. The assay may be placed directly upon the plaster tablet.

III. *Aluminium Plate as a Support in Blowpipe Analysis* :—Another substitute for charcoal is sheet aluminium, first introduced by Colonel W. A. Ross.* A strip of such sheet aluminium should be 5 inches long, $1\frac{1}{2}$ inches wide, and about the thickness of a ten cent piece; one end should be turned up to form a ledge, as directed by Ross, this ledge being between $\frac{1}{2}$ to $\frac{3}{4}$ inch wide and making rather less than a right angle with the rest of the plate. Sheet aluminium, even of much greater thickness than this, can be bent easily without any cracking, by heating it in a Bunsen burner, and working it while hot. After turning up the ledge, and rounding off the edges and corners with a file, the plate should be well scoured with bone ash and polished with leather and whiting, and may then be used for a long time.

* Alphabetical Manual of Blowpipe Analysis by Lieut.-Colonel W. A. Ross. London: Trübner & Co., 1880.

The test samples are either placed directly upon the metallic ledge, or are received on a small piece of charcoal half an inch square, and one-sixteenth of an inch in thickness, which can easily be cut and kept ready in large numbers.

When in use the plate is best held with spring forceps, described by Ross, though other forceps can be made to serve the purpose, the handles being covered with felt or flannel, as they get very hot. It is held so as to be almost vertical, only just enough inclined to prevent the assay and the slip of charcoal from falling off the ledge. A little practice enables the worker to hold it quite steadily with as much ease as he does the ordinary piece of charcoal. The plate, it is said, is not only a great gain as to portability, cleanliness, and economy, but also gives, in most cases, much better indications of the volatile substances sought for, which collect upon the larger vertical portion of the plate. Such a plate will last any length of time, as the hottest blowpipe flame, even one worked with a small hand-blower, does it no injury, and there is scarcely any substance (except melted gold) which may not be heated directly upon it with perfect safety. The one side being kept for sublimates, the other may be used for such purposes as calcining sulphides, etc., before testing in beads, for which it is far superior to charcoal, especially in the case of very fusible minerals. A fragment of the substance about half the size of a small pea, or if it decrepitates, a corresponding amount of powder made to a paste with water, is laid upon the ledge close up to the angle.

The *following,* according to W. M. Hutchings, are

the principal advantages of aluminium over charcoal:—

1. It enables us to get several sublimates in succession from the same fragment of substance. Heated very gently on the bare plate, only the most volatile constituents are given off.* As the heat increases, more and more are given off, but a limit is reached beyond which nothing is obtained, the less volatile constituents not being given off at all, or only very slightly, as long as the substance is cooled by lying directly on the aluminium. The same fragment being then placed on a slip of charcoal on the ledge, these less volatile constituents are obtained in the separate sublimates.

2. The sublimates are generally much more concentrated on the aluminium, as compared with ordinary charcoal, which, when exposed to the flame for any length of time, gets red hot some distance in front of the assay. The aluminium remains comparatively cool; and the vertical surface prevents the sublimates being swept along by the blast as much as on the nearly horizontal charcoal.

3. When the sublimate is once formed, the aluminium has no further action upon it, and many very characteristic changes may be observed by applying an oxidizing or reducing flame, most of which cannot be obtained at all on charcoal, partly because its being black would hide them, but chiefly because it immediately begins to glow under the sublimates when the flame is applied to them.

* When first applying heat, the point of the blowpipe flame ought to be held at a distance of 1 to 2 cm. from the assay.

5. FUEL LAMPS.

1. *Good stearine candles* will answer for most purposes.

2. *Olive Oil.*—A much better fuel is *olive oil*, *cotton-seed* or *rape-seed oil*, burnt in a brass lamp having a wick holder of circular or oblong section. This and the opening for filling the lamp are covered by screw caps, preventing all leakage.

Fig. 93 represents the form of blowpipe lamp invented by Berzelius, and improved by Plattner.

FIG. 93.

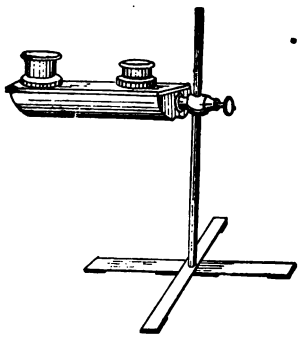


FIG. 94.

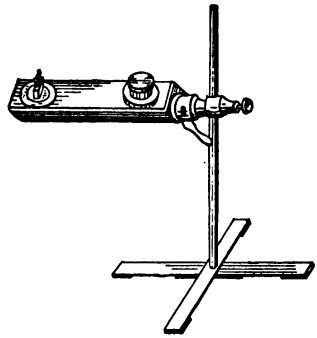


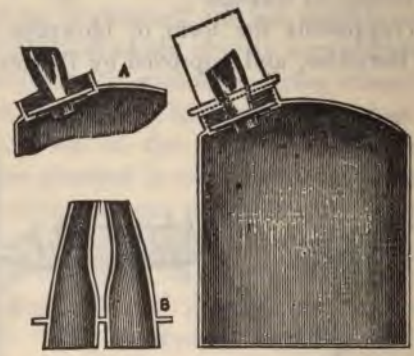
Fig. 94 is the Freiberg pattern of the same style of lamp as the preceding, but which revolves on its axis, permitting the flame from the blowpipe to be directed at any angle.

Another convenient lamp for using petroleum is Fletcher's improved blowpipe lamp, Fig. 95.

The wick holder, *A*, *B*, will be found one of the best forms ever made for burning light oils, in addition to the *fact that the angle* can be adjusted as required by

simply revolving it in the fixed collar. It lifts out for refilling. When used for olive or cotton-seed oil the wick holder figured must be replaced by one with an oblong opening of larger area, as the contraction of the tubes prevents the wicks drawing the heavier oil freely.

FIG. 95.



With this larger wick holder solid fats as stearine or paraffine may be used, the lamp being set upon a stove to melt the fat before being used. Solid fat is a convenient fuel for use when traveling. The above figure of the lamp is engraved half size.

FIG. 96.

An ordinary *alcohol lamp* of glass, Fig. 96, may also be used for blowpipe experiments, if the alcohol is mixed with turpentine or benzol (1 part of turpentine or 3 parts of benzol to 12 parts of strong alcohol of 80 to 90 per cent.).

3. Solid Fats—Lamps filled with solid fats, such as

tallow, paraffine, etc., have lately been introduced, which are convenient in traveling. Fig. 97 exhibits a modified form of the previously described lamp of Fletcher. It is made for tallow or solid fats for traveling. When tallow, etc., is used, the operation must be commenced by first blowing the flame downwards to melt the solid fat round the wick. The heat of the flame will keep it fused afterwards for any length of time. This pattern can be used with solid or liquid fats of any kind, and is a perfect traveler's lamp. Size, when closed, 2 in. by 2 in. Trim the wick always while the lamp is hot,

FIG. 97.

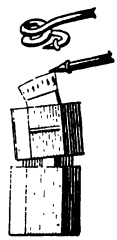
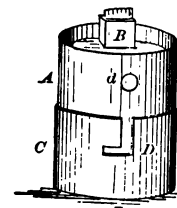


FIG. 98.



when hard fats are used. The curved bottom of the lamp should stand on the open end of the cover when in use. This makes a steady base, and admits of adjustment of the angle of wick without reversing or re-trimming.

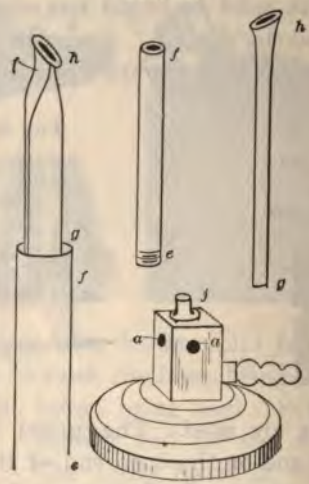
In Foster's lamp, Fig. 98, solid fat is likewise used, *e. g.*, paraffine or tallow. It serves as a traveler's lamp, and consists of a cylindrical vessel, *A*, to which the wick holder, *B*, is soldered. When in use the flame is at first directed downwards to melt the fat next to the wick, after which it yields a steady flame for hours.

The cover, *C*, forms also a support, and is fastened by a bayonet-socket, *D* (*d*).

6. ILLUMINATING GAS.

The most convenient combustible for blowpipe work is illuminating gas. The burner used is the ordinary Bunsen gas-burner, Fig. 99. For this purpose it is

FIG. 99.



provided with an extra tube, *g h*, to slip over the small gas jet at *j*, in the interior of the burner, *e f*, in such a manner as to shut off all excess of air at *a*. The tube is flattened at the top, see *f*, and made a trifle lower at one side, so that the blowpipe-flame may be directed downward when necessary. The gas is then lighted at the flattened end, *h*. A cock at the foot of the burner for regulating the flow of the gas is useful.

When testing substances for sulphur, the gas flame should not be employed, since the ordinary coal gas contains usually enough of sulphur to vitiate the results.

7. FIXED BLOWPIPES AND BLAST-LAMPS.

For many experiments it is of great advantage to have the blowpipe fixed to a support in order to leave the hands free for manipulation. The following, Fig. 100, represents an improved Herapath blowpipe for

FIG. 100.

general use. This is a modification of the well-known Herapath, from which it differs in its greater simplicity, and in its power of adjustment in any possible position. The jet tube may be raised or lowered to any height, and *turned in any* direction. A touch will direct the

flame on any point while the blowpipe stands in the same position on the table; there being no necessity for raising, lowering, or adjusting work before it.

Fig. 101 shows Fletcher's special chemical blowpipe with folding stand, adjustable at any height or angle. It can be used either with the mouth, or the small hand blower may be attached and the blowing done by the fingers. With this blowpipe is supplied one jet with,

Fig. 101.

and one without, the patent coil, to enable a larger variety of flame to be obtained. For all ordinary purposes the straight jet is to be preferred. The flame is more adjustable if the lamp is not placed upon the stand. The blower when not in use shuts up flat for the pocket. The pressure of air is adjusted by a delicate lever tap on the air tube.

8. PLATINUM APPARATUS AND APPLIANCES.

Platinum wire is used as a support when an assay is to be fused with borax or salt of phosphorus, etc., to ascertain the color of the beads produced. One

extremity of the wire, about three inches long and of the thickness of horse-hair, is bent into a round loop, about $\frac{1}{8}$ inch in diameter. This wire may be fused into a small glass-tube for a handle (Fig. 102), or a better handle may be made from a piece of wood of the thickness of a lead pencil which is split longitudin-

FIG. 102.

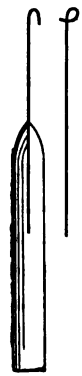
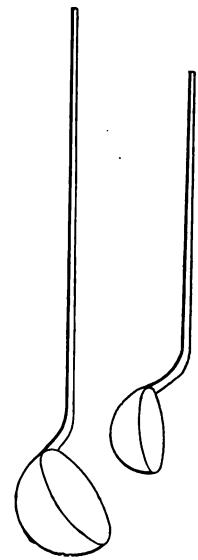


FIG. 103.



ally, the wire placed in the cleft, and the whole held together by a couple of sections of rubber tube slipped over the wood. Before being used, it should be thoroughly cleaned, by making several beads with the flux to be used and after heating for a minute throwing them out of the loop by a sudden jar.

Platinum spoons (*Fig.* 103, natural size) are very use-

ful for melting assays, and other operations. A glass, wooden, or cork handle should be adapted to it. A piece of platinum foil, properly bent, may be used for the same purpose as a spoon.

Forceps with platinum points (Fig. 104) to hold small

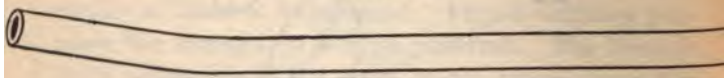
FIG. 104.

splinters of minerals in the flame to ascertain their fusibility.

9. TUBES OF HARD GLASS, FREE FROM LEAD.

They are one-twelfth to one-fourth inch in diameter, and four to six inches long, and are absolutely necessary. They serve for the ignition of mineral fragments in a current of air. The substance is placed near the

FIG. 105.



end, and the tube is then held somewhat inclined, either in the flame of a Bunsen burner or of the blowpipe. To prevent the falling out of the substance the tube may be slightly bent as represented in Fig. 105. For each new operation a clean tube must be employed.

Closed tubes and glass bulb-tubes, or matrasses (Fig. 106), are used for heating bodies out of contact with air. *They are easily* made of hard glass tubing before a

glass-blower's lamp, or a Bunsen-burner connected with a blast, as previously described. For chemical experiments a variety of *soft glass* tubing ought to be on hand; which, in the flame of a blast-lamp, can be readily bent or drawn out and sealed at one end.

Fig. 106.

A triangular file is used for cutting glass. A notch is cut in one side of the tube, when it is easily broken in two.

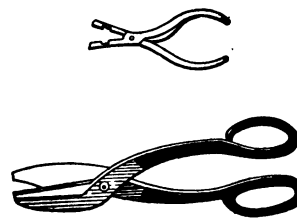
Watch-glasses are used for keeping powdered minerals and for various other purposes.

For other accessory apparatus—mortars, flasks, test-tubes, etc.—see Chapter III; and for acids and other chemicals, see Chapter IV.

10. CUTTING PLIERS; STEEL MAGNET; MAGNETIC NEEDLE.

Cutting pliers (Fig. 107) are useful for detaching frag-

Fig. 107.



ments from mineral specimens.

A common *steel magnet* serves to recognize magnetic *bodies.*

A *magnetic needle* is useful for delicate determinations.

11. BLOWPIPE REAGENTS.

The quantities used are small and there are but few which, however, have to be scrupulously pure. The dry preparations are generally purchased from dealers.

Carbonate of soda, called simply *soda*, Na_2CO_3. The bicarbonate of soda is generally more free from traces of sulphur than even the so-called C. P. carbonate. It should be ignited before using for fusions in closed tubes. *Borax* with water of crystallization, $Na_2B_4O_7 + 10H_2O$, and fused boric acid, B_2O_3, for the detection of copper in lead. Phosphate of soda and ammonia, salt of phosphorus or microcosmic salt, $Na(NH_4)HPO_4 + 4H_2O$. Cyanide of potassium, KCN (a *dangerous poison*). Bisulphite of potash or acid potassium sulphate, $HKSO_4$. Nitrate of potash, saltpetre, KNO_3. Iodide of potassium, KI. Sulphur, S. Flowers of sulphur. Nitrate of cobalt, $Co(NO_3)_2 + 6H_2O$ in solution; the crystals of the nitrate are dissolved in ten parts of water. For use the cobalt solution is most conveniently kept in dropping glasses.

Fig. 108, *a*, *b*, *c*, show different forms of this appara-

FIG. 108.

tus. *a*, according to Bunsen; *b* and *c*, according to Schuster, with and without a ground-glass stopper.

Oxalate of nickel, or nitrate of nickel, $Ni(NO_3)_2 +$

$6H_2O$. Black oxide of copper, or cupric oxide, CuO. Fluoride of calcium (fluor spar), CaF_2. The powder must be deprived of water by ignition. Nitroprusside of sodium for detecting sulphur.

Iron: Fine sifted iron filings. *Ferrum pulveratum*, or *alcoholisatum* of the druggists.

Lead: Pure lead or test lead.

Tin: Strips or tin-foil.

Zinc: Strip of common sheet zinc.

Magnesium: Bits of wire are useful in detecting phosphoric acid.

Silver-foil for the detection of sulphur. A smooth bright silver coin, however, will answer every purpose.

Bone-ash: A little cup of bone ashes, called a *cupel*, is used for the cupellation of gold and silver. It may be made by moulding the bone-ash into a cavity in a piece of charcoal.

Test-papers: Blue litmus paper, red litmus paper, turmeric paper, and Brazil-wood paper.

Charcoal.

Aluminium plate.

A small alcohol lamp.

Bottle for hydrochloric acid to test for carbonates, with a ground, tight glass stopper, reaching nearly to the bottom, thus enabling one to withdraw and use a single drop of acid. It may also be used for cobalt solution, Fig. 109.

FIG. 109.

12. PRELIMINARY TESTS OF INORGANIC SOLID SUBSTANCES.

The substances must be dry and in the form of fine powders. *In most of the* following experiments, the

blowpipe may be replaced by a Bunsen burner. The beads must be examined both hot and cold.

1. Easily volatilized when heated upon charcoal (or upon platinum foil or in a dry test-tube.)	Water; compounds of ammonia, mercury, and some of arsenic. Sulphur and its acids. Carbon burns by ignition in the air; all organic compounds are decomposed when heated, most of them with separation of carbon (blackening).
2. Deflagrate when heated upon charcoal.	Nitrates, chlorates, iodates, bromates, etc.; common salt, and other salts, as likewise many minerals, *decrepitate.*
3. Fusible without volatilizing and without changing color.	Most *salts of the alkalies* and some of those of the *alkaline earths.* After intense ignition in the R. F. they color moist turmeric paper brown.
4. B. B. infusible, or fusible with difficulty, without changing color.	The *earths* and their salts; most of the *alkaline earths* and their salts. When heated they glow with white light. The *earths* proper show no alkaline reaction after ignition. *Silica* and many of its compounds. Metals: Fe, Ni, Co, Pt, Mo, W, Pd, Ir, Rh.
5. Give when ignited with soda or soda and cyanide of potassium in the R. F. upon charcoal, or the luminous flame of a Bunsen burner:	*a. Garlic odor:* Most compounds of arsenic. *b. Hepar:* All compounds of sulphur. The mass when moistened blackens silver, and with acids develops sulphide of hydrogen. *c. Metallic grains:* Sn, Ag, Cu, Au. Gray *magnetic* powder: Fe, Ni, Co. Non-magnetic: Mo, W, Pt, Ir. Brittle: Sb, Bi. Malleable: Pb. Incrustation: Zn (white), Cd (brown).

6. Give, when heated in a glass tube open at both ends, and held obliquely:	*a.* *Odorous gases:* *Metallic* sulphides, of burning sulphur. Selenides, of decaying radishes. Arsenides, of garlic. Some ammoniacal salts yield NH_3, turning moistened red litmus paper blue. *b.* *Metallic coating:* Mercury and arsenic compounds. *c.* *White coating:* Metallic arsenides, antimonides, sulphide of lead, some salts of ammonia, such as sal-ammoniac.
7. Color the non-luminous flame of a Bunsen gas-lamp (O. F.):	*a.* *Yellow:* Na. *b.* *Violet:* K, Cs, Rb. *c.* *Crimson:* Li, Sr. *d.* *Blue:* As, Sb, Pb, Se. *e.* *Green:* Boracic acid; borates after moistening with sulphuric acid.
8. With phosphorus salt or borax upon platinum wire in O. F. and R. F. give:	*a.* *Colorless bead:* Silica. *b.* *Yellowish-brown or reddish:* Iron. *c.* *Amethyst color:* in O. F. (not in R. F.) manganese. *d.* *Blue:* Copper (in the O. F. only), Cobalt. *e.* *Yellowish-green:* Chromium.

CHAPTER V.

Reactions of Oxides with General Reagents.

The following reactions of oxides with borax and salt of phosphorus are taken from Wurtz's Dictionnaire de Chimie, vol. i., art. Chalumeau; the others from Landauer's Löthrohr-analyse, 2d edit., Berlin, 1881.

1.- Behavior of Metallic Oxides with Borax.

or of bead.	In the oxidizing flame.		In the reduction flame.	
	Hot.	Cold.	Hot.	Cold.
rless.	Si, Al, Sn, Ba, Sr, Ca, Mg, Be, Y, Zr, Th, La, Te, Ta, Nb, W, Mo, Ti, Zn, Cd, Pb, Bi, Sb, only in s. q. or yellow.	Si, Al, Sn, Ba, Sr, Ca, Mg, Be, Y, Zr, Th, La, Te, Ta, Nb, Ti, W, Mo, Zn, Cd, Pb, Zn, Ag, white by fl., Fe in s. q.	Si, Al, Sn, Ba, Sr, Ca, Mg, Be, Y, Zr, Th, La, Di, Mn, Nb, only in s. q., or else gray and op., Ag, Zn, Cd, Pb, Bi, Sb, Ni, Te by c. b. or else gray and op.	Si, Al, Sn, Di, Mn, Ba, Sr, Ca, Mg, Be, Y, Zr, Th (saturated), La, Ce, Ta, white and op. by fl., Nb, in s. q., or else gray and op., Ag, Zn, Cd, Pb, Bi, Sb, Ni, Te, by c. b., or else gray and op., Fe, in s. q.
and aque.	"	"	Ag, Zn, Cd, Pb, Bi, Sb, Ni, Te, especially cold and by little blowing, or else colorless, Nb, in s. q.	Ag, Zn, Cd, Pb, Bi, Sb, Ni, Te, by blowing little, or else colorless; Nb, in s. q.
pale low.	Ag, in s. q.	Ag, in l. q. by fl.	"	"
yel- v.	Ag, Cd, Zn, in l. q.	"	"	"
ow.	Ti, W, Pb, Sb, Mo, in l. q., U, in s. q.	V, Fe, Ce, white op. by fl., U, yellow, op. by fl.	Ti, in s. q. or else bluish - violet, Mo, in s. q., in l. q., brown, W, Va.	Mo, in l. q. op., and brown, W. in l. q. brown.
ge.	Cr, Fe, in l.q., Bi, in l. q.	"	U.	"
	Ce.	"	"	"
) red.	Fe, in l. q.	Mn (violet-red).	"	"
rnish- l.	Cr, U.	Ni.	Cu, by blowing little (muddy).	Cu, by blowing little (muddy).
et.	Mn, Ni, Di.	Di.	"	Ti, op. by fl.
.	Co.	Co, Cu green when getting cold.	Co.	Co, Cu, nearly colorless by c. b.
n.	Cu.	Cr, yellowish when getting cold.	Fe, Cr, brownish, Cu, nearly colorless by c. b.	Fe, U, bottle-green, Cr, V, emerald-green.

E.—*Abbreviations* employed: s. q., small quantity; l. q., large quantity; *flaming; c. b., continued* blowing; op., opaque.

2. Behavior of Metallic Oxides with Salt Phosphorus.

Color of the bead.	In the oxidizing flame.		In the reduction f	
	Hot.	Cold.	Hot.	(
Colorless, a portion of the substance undissolved (silica skeleton).	Si	Si	Si	
Colorless.	Al, Sn, Ba, Ca, Mg, Be, Y, Zr, Th, La, Nb, Te, in all proportions; Ta, Ti, W, Zn, Cd, Pb, Bi, Sb, in s. q. or else more or less yellow.	Al, Sn, Ba, Sr, Ca, Mg, Be, Y, Zr, Th, La, Te, W, Zn, Cd, Pb, Bi, Sb, Fe, in s. q.	Al, Sn, Ba, Sr, Ca, Mg, Be, Y, Zr, Th, La, Ce, Di, Mn, Ta, Ag, Zn, Cd, Pb, Bi, Sb, Ni, Te, by very long c. b., or else gray and op.	Al, S Co, Zr, ated by Mn, Zn, Bi, by c gray Fe i
Gray and opaque.	"	"	Ag, Zn, Cd, Pb, Bi, Sb, especially when cold, Te, Ni.	Ag, Z Bi,
Pale yellow.	Sb, Zn, in l. q.	Ag, Fe.	"	Fe (g
Yellow.	Pb, very l. q., Bi, Cd, Ta, Ti, W, in l. q., Ag, Ca, Ni, U, V, Cr, Fe, in s. q.	Fe, in l. q.; Ni, in s. q., U (greenish), V.	Ti.	Fe (g
Orange.	Cr, Fe, in l. q.	Ni, in l. q.	Fe, in s. q., V.	Fe wh
Red.	"	"	Fe (brown).	
Deep red.	"	"	"	C
Reddish-brown.	Fe, Cr, in very l. q.	"	Cr.	C
Violet.	Mn, Di.	Mn, Di.	Nb, in l. q.	N
Blue.	Co.	Co, Cu (greenish when getting cold).	Co; W, Nb, in very l. q.	Co; ve
Green.	Cu, Mo (yellowish).	Mo, U, yellowish, Cr, emerald green.	U, Mo, Cu.	Cr, U

Note.—Abbreviations employed: s. q., small quantity; l. q., lar
fl., by flaming; c. b., continued blowing; op., opaque.

3. EXAMINATION OF MINERALS WITH SODA (*Sodium Carbonate*), Na_2CO_3.

The examination with soda is generally performed on charcoal in the reduction flame, and as a general rule the flux is added successively in small portions. It is sometimes better to form the finely pulverized assay into a paste with moistened soda before placing it upon the charcoal. This is particularly necessary when the assay is to be tested for its fusibility with soda, since a great many minerals and ores behave quite differently with different quantities of flux.

Instead of sodium carbonate, the neutral *potassium oxalate* or *potassium cyanide* may advantageously be used for all experiments of reduction, since these reagents exercise even a more powerful reducing action than soda. They are for this reason frequently employed when the presence of such metallic oxides is suspected, whose conversion into metals requires a high temperature and the aid of a very efficient deoxidizing agent.

In subjecting a body to the treatment of soda, we must direct our attention to two points: First the formation of a compound with the soda, and second the reduction of oxides to metals. Some substances unite with soda to form *fusible compounds*, others form *infusible compounds*, and others again are not *fused at all;* in the last case the soda is simply absorbed by the charcoal, and the assay is left completely unchanged.

With soda, the following substances produce fusible compounds with effervescence of carbon dioxide (CO_2):—

Silicic oxide.—Silica (SiO_2)* fuses to a transparent glassy bead which, after cooling, remains transparent if the soda has not been added in too great excess.

Titanium dioxide (TiO_2) fuses to a transparent glassy bead, which is dark-yellow while hot, but on cooling becomes turbid and crystalline.

Tungsten trioxide (WO_3)† and *Molybdenum trioxide* (MoO_3)‡, after the carbon dioxide is driven off, are absorbed by the charcoal.

Tantalum pentoxide (Ta_2O_5), *Vanadium pentoxide* (V_2O_5), and *Niobium pentoxide* (Nb_2O_5) also yield fusible compounds and sink into the charcoal.

Lime, magnesia, zirconia, thoria, yttria, and glucina (beryllium oxide), as well as cerium and uranium oxides, are not attacked: they remain unchanged, while the soda sinks into the charcoal.

The salts of barium and strontium form, with soda, fusible compounds, which are absorbed by the charcoal.

Sodium carbonate is also used for the detection of—

a. Sulphur, selenium and *tellurium compounds*, which give with it a fused mass,§ yielding a black, or brown, stain when laid upon a piece of silver and moistened with water.

b. Manganese and *chromium*, with the soda alone, O. F.,

* Silica belongs to the class of acid-forming oxides, and the silicic acid corresponding to the oxide SiO_2 must have the formula H_4SiO_4 or $Si(OH)_4 = SiO_2 + 2H_2O$.

† Tungstic acid (wolframic acid) $= H_2WO_4$.

‡ Molybdic acid $= H_2MoO_4 + H_2O$.

§ Hepar sulphuris (liver of sulphur).

or better, with addition of sodium nitrate, yield on platinum foil colored masses; the former a green mass of manganate, and the latter a yellow mass of chromate.

The second point to be observed is the reduction of oxides to metals with the elimination of this metallic matter from the soda fusion.

When treated with soda on charcoal in the R. Fl., the following metallic oxides are reduced: The oxides of the noble metals and the oxides of arsenic, antimony, bismuth, indium, cadmium, copper, cobalt, iron, lead, mercury, nickel, tin, zinc, molybdenum, tungsten, and tellurium. Of these, arsenic and mercury vaporize so rapidly that frequently not even a coating is left on the charcoal. Antimony, bismuth, cadmium, lead, zinc, and tellurium are partially volatilized, and form distinct coatings of oxides on the charcoal.

The reduced non-volatile metals are found mixed with the soda. To separate them from the adhering soda and charcoal powder, we proceed in the following manner: The fused mass of soda and metal, and the portion of the charcoal immediately below and around the assay, are placed in a small agate mortar, ground to powder, then mixed with a little water and stirred up. The heavy metallic particles settle to the bottom, a portion of the soda dissolves, and the charcoal powder remains suspended in the water. The liquid is carefully poured off, and the residue treated repeatedly in the same manner until all foreign matter is removed. The metal remains behind as a dark heavy powder; or, when the metal is ductile or easily fusible, in the shape of small flattened scales with metallic luster. These may be examined with the magnifying glass and also

with the magnet. If the substance under examination contains several metallic oxides, the metallic mass obtained is usually an alloy, in which the several metals may be detected by processes to be described hereafter. It is only in some exceptional cases that separate metallic globules are obtained, as, for example, in substances containing iron and copper.

4. EXAMINATIONS OF METALS WITH SODIUM THIOSULPHATE (HYPOSULPHITE OF SODIUM), $Na_2S_2O_3$.

With all the metals which can be precipitated in the *wet way* by hydrogen sulphide, the same reaction may be obtained in the *dry way* by heating the powdered substance with powdered *thiosulphate of sodium* in a reagent tube. After the decomposition has taken place —recognized by the evolution of hydrogen sulphide— the melted mass exhibits very clearly the peculiar coloration of the metallic sulphides produced. In many cases this reaction is enhanced by a small addition of *oxalic acid*.

Since the *thiosulphate of sodium* contains considerable water of crystallization, the greater portion of this must be removed from this reagent before experimenting, or the glass tube must be held horizontally to prevent its cracking, in which case the open end had better be closed with cotton-wool.

The sulphide reactions of the metals are demonstrated in the following table, in which their behavior with *borax* on platinum wire is shown by way of comparison. These methods supplement each other very instructively.

5. TABULAR ARRANGEMENT SHOWING THE BEHAVIOR OF OXIDES, WHEN TREATED BEFORE THE BLOWPIPE, WITH SODIUM THIOSULPHATE, TOGETHER WITH THEIR REACTIONS WITH BORAX.

Metallic oxides.	Behavior with $Na_2S_2O_3$.	Behavior with borax on platinum wire (the bead cold).	
		Oxidizing flame.	Reducing flame.
Antimony oxide	Orange-red,	Colorless,	Gray to colorless.
Arsenic "	Lemon-yellow,	Vaporizes,	Vaporizes.
Bismuth "	Black,	Colorless,	Gray to colorless.
Cadmium "	Yellow,	Colorless,	Gray to colorless.
Chromium "	Green,	Grass-green,	Emerald-green.
Cobalt "	Black,	Blue,	Blue.
Copper "	Black,	Bluish-green,	Brown.
Gold "	Black,	Reduced to metal	without dissolv'g.
Iron "	Black,	Yellow,	Bottle-green.
Lead "	Black,	Colorless,	Gray to colorless.
Manganese "	Light-green,	Violet(amethyst)	Colorless.
Mercury "	Black,	Vaporizes,	Vaporizes.
Molybdenum "	Brown,	Colorless,	Brown.
Nickel "	Black,	Reddish-brown,	Gray to colorless.
Platinum "	Black,	Reduced to metal	without dissolv'g.
Silver "	Black,	Colorless,	Gray to colorless.
Thallium "	Black,	Colorless,	Colorless.
Tin "	Brown,	Colorless,	Colorless.
Uranium "	Black,	Yellow,	Bottle-green.
Zinc "	White,	Colorless,	Gray to colorless.

6. EXAMINATION WITH ACID POTASSIUM SULPHATE, OR CONCENTRATED SULPHURIC ACID.

To determine the presence of volatile acids, a small quantity of the substance is heated with acid potassium sulphate, or with concentrated sulphuric acid (in the latter case, however, not to the boiling-point of the acid), and *the following* appearances noticed:—

A. A Colored Gas is Evolved.

a. Nitrogen tetroxide (NO_2) fumes are recognized by their reddish-brown color and characteristic odor; evolved from nitrates and nitrites. With nitrates the reaction is promoted by the addition of copper filings.

b. Chlorine tetroxide (hypochloric acid), Cl_2O_4, yellowish-green, odor like chlorine, bleaches litmus paper. The evolution of this gas by this treatment indicates the presence of chlorates.*

c. Iodine, from iodides, may be recognized by its violet vapors, which color starch paper blue. Iodates* give this reaction after the addition of ferrous sulphate (copperas).

d. Bromine; reddish-brown vapors, with pungent, unpleasant odor, which turn starch-paste yellow. Yielded by *bromides* and *bromates*. The color of the vapor is best seen on looking down the tube.

B. A Colorless, Odorous Gas is Evolved.

a. Sulphur dioxide (sulphurous anhydride), evolved from sulphites and polythionates, is easily recognized by its suffocating odor and bleaching properties (litmus, etc.).

b. Hydrochloric acid, from chlorides, recognized by its odor and by the clouds of ammonium chloride (sal-ammoniac) which are formed, when a glass-rod, moistened with ammonia-solution, is held over the tube.

c. Hydrofluoric acid, from fluorides, fumes, has a very suffocating odor, and strongly etches glass.

* The chlorates, iodates, and bromates deflagrate when heated on *charcoal.*

d. Hydric sulphide (sulphydric acid, sulphide of hydrogen, sulphuretted hydrogen), H_2S, from sulphides, of a repulsive odor, blackens paper moistened with lead acetate (sugar of lead) solution.

e. Cyanic acid, from cyanates, has a characteristic pungent odor; it brings tears to the eyes, and renders lime-water turbid.

f. Acetic acid, from acetates, is known by its pungent, "vinegar" odor, and also by yielding fragrant acetic ether on heating with sulphuric acid and alcohol.

C. A COLORLESS AND ODORLESS GAS IS EVOLVED.

a. Carbon dioxide (carbonic acid gas), CO_2, is expelled from carbonates with effervescence; it renders lime-water turbid.

b. Carbon monoxide (carbonic oxide), CO, which burns with a bluish flame, may arise from oxalates, formates, cyanides, ferrocyanides, and ferricyanides.

c. Chromic acid evolves *oxygen*, and the liquid turns brown or green.

d. Organic acids are recognized by the blackening due to the separation of carbon (except oxalic acid, which yields CO and CO_2).

The acids which cannot be detected by the above methods, though easily detected in other ways, are: Sulphuric, phosphoric, arsenic, boric, silicic, tungstic, molybdic, and titanic.

7. EXAMINATION WITH ZINC OR TIN AND HYDROCHLORIC ACID AFTER PREVIOUS DECOMPOSITION (FUSION) OF THE MINERAL.

A mixture of sodium carbonate and nitre is added to

the finely-powdered assay, the mass is moistened slightly, and placed in a small spiral of platinum wire, of about 2 to 3 mm. diameter. After fusing for a short time, the glowing mass in the spiral is thrown off into a porcelain dish and digested with a little water in a test-tube. Afterwards a little hydrochloric or sulphuric acid is added, and a strip of zinc or tin is brought into the solution. By the reducing agency of the nascent hydrogen thus formed, various colors are produced as shown in the following table :—

Molybdic trioxide (molybdic acid) : Blue, then green, finally blackish-brown.

Tungsten trioxide (Tungstic acid) : Blue, then copper-red.

Columbium (niobium) *pentoxide* (niobic acid) : Blue, often also brown (with strongly acid solution).

Vanadium pentoxide (vanadic acid) : Blue, then green, finally violet.

Chromium trioxide (chromic acid) : Green.

Titanium dioxide (titanic acid) : Violet.

8. EXAMINATION WITH COBALT SOLUTION.

A few substances, when moistened with a solution of cobalt nitrate and exposed to the action of the O. Fl. assume a peculiar color. The use of this test is, however, very limited, since the reaction can only be clearly seen in those bodies which, after having been acted upon by the O. Fl., present a white appearance or nearly so.

Substances which are sufficiently porous to absorb a liquid are merely moistened with a drop of cobalt solution, held with the platinum-forceps, and submitted to

the O. Fl. Other substances must be powdered, the powder placed on charcoal, moistened with a drop of cobalt solution, and treated as above. The color can only be distinguished after cooling. A bluish color of more or less purity, but rather dull, indicates the presence of alumina, and a flesh-color (pale-reddish color) that of magnesia. It must, however, be borne in mind that the alkaline and some other silicates, when heated with cobalt solution to a temperature above their fusing points, also assume a blue color, owing to the formation of cobalt silicate. In testing for alumina, therefore, the heat must not be raised so high as to cause fusion of the assay. In testing for magnesia this precaution is not necessary ; as, on the contrary, the color will appear the brighter and the more distinct the higher the temperature to which the assay is exposed. The alumina and magnesia reactions are prevented by the presence of colored metallic oxides, which generally produce a gray or black mass, unless present in very minute quantity.

Among the oxides of the heavy metals, those of zinc and tin assume characteristic colors with solution of cobalt. The reaction is best seen when the assay, alone or mixed with soda, is exposed to the R. Fl. on charcoal. The ring of oxide which is deposited around the assay is then moistened with solution of cobalt and treated with the O. Fl. Zinc takes a fine yellowish-green, and tin oxide a bluish-green color.

Besides the compounds above mentioned, there are some others which, when exposed to the action of cobalt solution and heat, experience a change in color, but still this reagent does not justify its employment

for their recognition. In fact, only the colorations of alumina, magnesia, zinc, and tin are of real value in the determination of these substances.

The following table gives the more definite colorations caused by cobalt solution :—

Blue: Alumina ; deep color ; infusible.
Silica and silicates ; pale blue ; with much solution, black or dark gray. Thin edges of assay fuse to a reddish-blue glass at a high temperature.
Phosphates, borates, and silicates of the alkalies yield a blue glass.
Green: Zinc oxide, Titanium dioxide } yellowish-green.
Tin oxide ; bluish-green.
Antimony oxide ; impure green.
Flesh-red: Magnesia ; pale flesh-red or pink.
Tantalum pentoxide ; hot, light ; cold, flesh-red.
Violet: Zirconia ; impure violet.
Magnesium arsenate and phosphate fuse and become violet-red.
Brown: Baryta ; hot, reddish-brown or brick-red ; cold, colorless.
Gray: Strontia ; dark-gray to black.
Lime ; gray.
Glucina ; bluish-gray.
Columbium (niobium) pentoxide ; brownish-gray.

CHAPTER VII.

Colored Flames, and Bunsen's Flame Reactions.

1. Examination of the Assay in the Platinum Forceps or Wire for Flame Colorations.

Many substances, especially the alkalies and alkaline earths, when brought into a non-luminous flame, impart to it distinct colorations, affording in many cases characteristic means for detecting them even in the minutest quantities, *e. g.*, sodium salts tinge the flame yellow; potassium compounds, violet; strontium salts, scarlet-red; lithium salts, carmine-red, etc.

The Bunsen burner, previously described (Fig. 71), is especially well adapted to such observations. The coloring substance may be brought on a platinum wire loop into the zone of fusion of the flame. When mixtures of different flame-coloring substances are examined, indecisive tests are usually produced; thus, in a mixture of sodium and potassium salts, only the yellow sodium flame is evident, but by viewing the flame, as recommended by Bunsen and Merz, through colored glasses or fluids, the mixed colors may be dissected.

The apparatus for these observations is simple, viz., a blue, a violet, a red, and a green glass. The stained glasses found in commerce possess generally the proper shade of color. Indigo solution may be substituted for

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blue glass. A hollow prism is used (Figs. 110 and 111), made of plate glass, whose principal section forms a

FIG. 110.

triangle 150 millimetres in length, and 35 millimetres in diameter at the thick end. The solution with which it is filled is prepared by dissolving 1 part of indigo powder in 8 parts of strong sulphuric acid, heating the mixture on the sand-bath, and stirring it frequently with a glass rod. The syrupy solution thus obtained is diluted with 1500 to 2000 parts of water,* and filtered through felt or thick blotting paper. Of the colored glasses of commerce the blue is colored by cobalt protoxide; the violet by manganese sesquioxide; the red (partly colored and partly uncolored) by cuprous oxide; and the green by iron sesquioxide and cupric oxide. Merz,† who has made a complete study of this subject, employs with these glasses Bunsen's burner, and also a flame of pure hydrogen. The substances which he describes as giv-

FIG. 111.

*The cold indigo solution must be gradually poured into the proper amount of water, the reverse operation might prove dangerous.

†G. Merz, Flammenfärbungen, Journ. f. pract. Chemie. Bd. 80, p. 487.

ing characteristic colors to the flame of a Bunsen burner, in addition to those previously known, are nitric and chromic acids, while phosphoric and sulphuric acids give a peculiar coloration to the dark core of the flame of hydrogen.

The flame of Bunsen's burner, which is preferred for these reactions, gives three sorts of colors.

1. *Border colors.* These are of course peculiar only to the most volatile substances. To produce them, the loop of platinum wire is held outside of the flame about one or two millimetres from the lower portion of the outer limit.

2. *Mantle colors.* Those which are seen when the substance is held in the bright blue-colored mantle which forms the outer portion of the flame.

3. *Flame colors.* To produce these, the loop is to be held horizontally and in the hottest part of the mantle. The *hydrogen flame* yields another fourth species of color, viz., the

4. *Core colors.* They are produced only by sulphuric and phosphoric acids, which communicate respectively a blue and green tinge to the cold core of the hydrogen flame.

2. FLAME COLORATIONS.

All flame-coloring substances may, according to their volatility, be arranged in three classes: 1. Certain acids; 2. Alkalies; and 3. Alkaline earths, to which may be added the heavy metal, copper. If the substances are brought into the flame of the Bunsen burner mentioned on page 107, we may detect

Acids.

a. Nitric and nitrous acids give a bronze-green border color, usually with an orange-colored margin. The assay is to be previously dried in the flame, and then either moistened with HCl, or dipped into a solution of acid potassium sulphate, according as we wish to test for nitrous or nitric acid. Ammonium and cyanogen compounds give the same reaction but more faintly.

b. Phosphoric acid gives a gray yellowish-green border color, after moistening with sulphuric acid. In the presence of boric acid, phosphoric acid can only be discovered by the intense green flame produced by heating the assay in a hydrogen flame after moistening with a solution of hydrofluosilicic acid. For this purpose the hydrogen is delivered from a platinum jet; for instance, the side tube of a blowpipe.

c. Boric acid gives a beautiful green mantle color, which is so intense that this acid may be recognized in the presence of considerable quantities of phosphoric acid. Borates require to be first decomposed with sulphuric acid, or the fluor spar and potassium bisulphate mixture.

b. Molybdic acid yields a yellowish-green flame similar to that shown by barium salts.

e. Hydrochloric acid gives a very weak greenish blue border color which lasts but an instant, and hence frequently escapes detection.

f. Sulphuric acid produces a fine blue core color, being reduced to sulphur dioxide. The free acid gives the color when the platinum wire loop is held in the border of the flame, but a sulphate must be held in the *middle of the flame.* In the latter case it is best to

first dip the assay into concentrated hydrochloric or hydrofluosilicic acid.

g. Chromic acid gives a dark brownish-red border color and a rose-red mantle color. The dry assay is to be moistened with concentrated *sulphuric acid*, and held in the border. *Chromic oxide* gives no color, and should be first oxidized to chromic acid by moistening with a solution of sodium hypochlorite and drying.

Alkalies.

a. Potassium gives a grayish-blue mantle color and a rose-violet flame color. The color appears reddish-violet through a blue glass* (detection in presence of sodium), violet through violet-colored glass, and bluish-green through green glass. The assay is to be moistened with sulphuric acid, and repeatedly exposed to the flame for a short time.

b. Sodium gives an orange-yellow flame color, which in quantity appears blue through blue glass, but which is invisible when present in small amounts. Seen through green glass, the flame has an orange color, characteristic of all sodium compounds. If a crystal of potassium-bichromate is held near to the sodium flame, the former becomes quite colorless, and a red spot of mercuric iodide on paper becomes white with a faint tinge of fawn color. The assay is moistened with sulphuric acid, dried, and then held in the hottest part of the flame.

c. Lithium yields a carmine-red flame color, which appears violet-red through blue glass, and carmine-red

*Cartmell, Phil. Mag., May, 1858, p. 328.

through violet glass. In the presence of sodium, lithium is detected by the blue glass. In the presence of potassium, Bunsen's method is employed. The assay is brought into the zone of fusion of a Bunsen gas-lamp, and this flame is compared simultaneously, through an indigo prism, with one obtained from a pure potassium salt held in the corresponding part of the flame opposite to the assay. Through the thinnest layer of the solution the lithium flame appears redder than the pure potassium flame; through thicker layers the flames appear equally red, when the proportion of lithium to potassium is very small. If, however, lithium predominates in the assay, the intensity of the red flame diminishes rapidly as the prism is moved, whilst the pure potassium flame is scarcely any feebler. Sodium, when not present in large excess, modifies these effects but slightly.

Potassium and lithium are not likely to be confounded with strontium if the assay be treated as described under potassium, since strontium compounds are not volatilized at the low temperature thus obtained.

Alkaline Earths.

The assay is repeatedly moistened with sulphuric acid, dried, and placed in the hottest part of the mantle. After all the alkalies are volatilized the following reactions appear:

a. Barium gives a yellowish-green flame color, which appears bluish-green through green glass. If the green disappears, and a red color makes its appearance, the assay is to be repeatedly moistened with hydrochloric acid, and immediately introduced while wet into the

hottest part of the flame. When the bluish-green color is no longer seen we proceed to test for calcium.

b. Calcium is present when the red flame color, on evaporating the last portion of hydrochloric acid (recognized by a spitting of the assay), appears finch-green through the green glass.

c. Strontium is known by the purple to rose color, which appears through blue glass, as the assay spits in the flame after being moistened with HCl. Under identical conditions calcium gives a faint greenish-gray color.

Copper.

Copper chloride yields a sky-blue flame color; the nitrate gives a pure green one. By the combined observations of both colors, copper may readily be distinguished from all other metals which give similar colors.

The remaining flame-coloring metals, such as arsenic, antimony, tin, lead, mercury, and zinc, exhibit, especially in the form of chlorides, more or less intense bluish or greenish mantle colors, which, however, are of no great value in analysis. As a rule the appearance of these colors can be prevented by moistening with sulphuric acid. It is best, however, to expel on charcoal those metals which give an incrustation, before testing for alkalies or alkaline earths by flame coloration.

In order to detect the alkalies in silicates it is sufficient to decompose the assay on platinum wire with some pure gypsum (sulphate of lime). If, on the contrary, the alkaline earths are looked for, the decomposition *must be effected* by means of sodium carbonate.

The substance is fused with the reagent in a platinum spoon, the fused mass extracted with water, and the residue treated with HCl, when silicic acid separates out, and the solution is then examined in the flame.

In order to detect several flame-coloring elements when occurring together, the use of the spectroscope may be resorted to, instead of using the colored glasses. The direct-vision pocket spectroscope, such as that of Browning and others, is well adapted for blowpipe investigations.

The following table gives the more definite flame colorations:—

Red Flames.

Lithium: carmine-red.

Strontium: scarlet-red.* } Barium salts obscure the reaction.
Calcium: yellowish-red.* }

Violet Flames.

Potassium: violet-red. Sodium and lithium salts obscure the reaction.

Caesium: } Like potassium.
Rubidium: }

Yellow Flames.

Sodium salts.

Green Flames.

Copper oxide: emerald-green; when moistened with HCl, blue.
Thallium: grass-green.
Phosphoric acid: yellowish-green. } After their salts are moistened with sulphuric acid.
Boric acid: bluish-green. }
Barium salts: yellowish-green.*
Molybdic acid: faint yellowish-green.
Tellurous acid: green, giving off fumes.
Nitric and nitrous acid: bronze-green, disappearing quickly.
Zinc: pale bluish-green.

* Especially after moistening with HCl.

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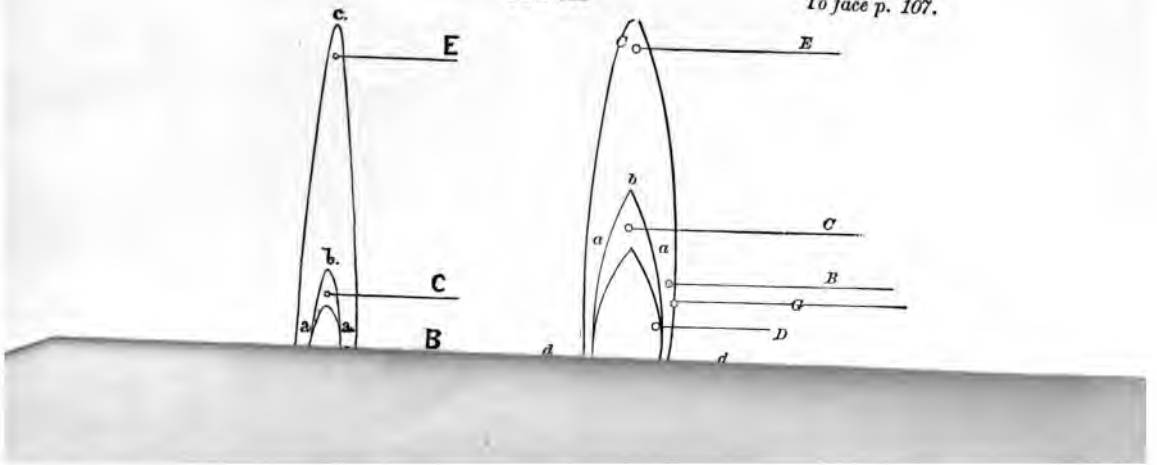
FIG. 112

To face p. 107.



Blue Flames.

Copper chloride: azure-blue, afterwards green.
Iridium: indigo-blue (in both flames).
Selenium: cornflower blue, accompanied by the odor of rotten horse-radish.
Arsenic: bluish.
Antimony: faint greenish-blue.
Lead: blue.

3. BUNSEN'S GAS-LAMP, AND REACTIONS WITH THE BUNSEN BURNER.

According to Bunsen, most of the tests obtainable with a blowpipe can be produced by means of the non-luminous flame of a Bunsen burner, Fig. 83, provided with a movable collar, *m* (by turning of which the access of air may be regulated), and a conical chimney, *d*, *d*, *d'*, *d'*, of such dimensions that the flame burns perfectly steady. The flame should have the dimensions shown in Fig. 112.

The *six portions* of the flame, which serve for conducting the different reactions, are distinguished as follows:—

I. The *base of the flame* at *A*, having the *lowest temperature*, is especially adapted for separating from a mixture of flame-coloring substances the most volatile ones first.

II. The *zone of fusion* at *B*, having the *highest temperature*, is therefore particularly suited for testing the fusibility, volatility, etc., of an assay.

III. The *lower oxidizing flame* at *G* is especially employed for the higher oxidation of oxides dissolved in fused beads.

IV. The *upper oxidizing flame* at *E* acts with the

greatest power when the draft holes, *h*, are completely opened. All the roastings and oxidations are here executed, provided that not too high a temperature is required.

V. The *lower reducing flame* at *D*, less energetic than the following, gives for that very reason peculiar reactions; it serves especially for reductions on charcoal, and of beads of fused salts.

VI. The *upper reducing flame* at *C*. The point *a b a*, above the *dark cone* of the flame, is not visible when the draft holes, *h*, are entirely open; but if this luminous point is made *too* large, soot is deposited, which is not desirable. This part of the flame is particularly suitable for the reduction of metals which it is desired to collect as metallic incrustations or coatings.

The following apparatus serves as a support for bringing specimens into the flame:—

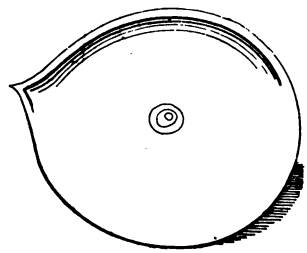
4. APPARATUS AND METHOD EMPLOYED FOR SUBMITTING SUBSTANCES TESTED TO THE FLAME.

Behavior of the Elements at High Temperatures.—This is one of the most important reactions which can be employed for the detection and separation of substances. To produce with the flame alone a temperature as high or higher than that of the ordinary blowpipe, the radiating surfaces of the heated body must be as limited as possible, and therefore be on a very small scale.

By bringing the moistened loop of the platinum wire (of the thickness of a horse hair) in contact with the powdered substance that is to be examined, a portion of it adheres; and when the loop is held for some time near the flame, and finally within it, the substance

sinters or fuses firmly upon the wire. When the substances act upon platinum, a thread of asbestos is used. Salts that decrepitate are ground to the finest powder in the porcelain capsule, Fig. 113, with the elastic blade of the knife, Fig. 114, and drawn up on to a moistened strip of one square centimetre of Swedish

FIG. 113.



filter paper. If the paper is then burnt, being held with the platinum forceps, or better, between two rings of fine platinum wire, the sample remains as a coherent crust, which may now, without difficulty, be heated in the flame.

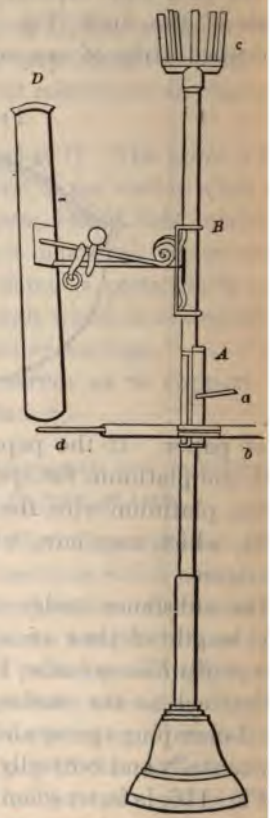
The substance under examination may be kept for any length of time in a given part of the flame by means of a *Bunsen holder*, Fig. 116. The arm, *a*, Fig. 116, is fastened to the carrier, *A*, so fixed on the stand by a self-clamping spring slide, that it can be moved both horizontally and vertically. The glass tube, Fig. 115 and *d*, Fig. 116, is fastened on this arm, *a*, and the fine platinum wire (fused into the glass tube) thus held in the flame. Splinters (fibres) of asbestos are inserted in the glass tube, *b*, which slips into the holder, and may be

moved with the carrier, *A*. The carrier, *B*, is provid
with a spring-clamp for holding test-tubes, which ha

FIG. 114.

FIG 115.

FIG. 116.



to be heated for a considerable time in a particular p
of the flame. The little turn-table, *c*, contains ni

upright supports for storing the wire tubes employed in the experiments.

For testing liquids, the wire of the loop is flattened by a few taps with a hammer; then, if dipped into the solution, it lifts up a drop, which, by holding it near the flame slowly evaporates, and the residue, if any, may be brought into the *zone of fusion*. By means of these arrangements, a small portion of the substance may be brought into the flame, and its behavior in the coldest and hottest parts of the flame ascertained, the substance being examined with a lens after each change of temperature.

Platinum wire, no thicker than a horsehair (*i. e.*, a piece 1 decimetre long, must not exceed 0.034 grm. in weight), is used in experiments for examining the fusibility, volatility, flame coloring, and also for reactions with borax, salt of phosphorus, and soda.

Fibres of asbestos, about one-fourth as thick as an ordinary match, serve instead of platinum (where this metal is attacked), and are moistened before receiving the test substance.

Charcoal rods as a substitute for ordinary charcoal. They are prepared from ordinary friction matches; the head is broken off and three-quarters of its length coated with fused, crystallized sodic carbonate, and charred in the flame with a rotary motion. The rods when thus glazed are partially protected against combustion.

Tubes of thin, hard glass 3 cm. long, 2 to 3 mm. wide, and closed at one end.

5. Reagents.

The following chemical reagents are specially employed for Bunsen's flame reactions:

Stannous chloride ($SnCl_2$). The solution must be kept in a glass-stoppered bottle. In order to prevent its transformation to stannic chloride ($SnCl_4$) a few small grains or pieces of metallic tin are placed in the bottle. The salt is a powerful reducing agent, and serves to distinguish metallic coatings, and for the recognition of *Gold*, *Molybdenum*, *Tungsten* (*Wolfram*), etc.

Caustic soda solution, (NaOH), is likewise employed for recognition of metallic coatings, as also for the recognition of *Cobalt*, *Nicket*, *Tin*, etc.

Nitrate of silver solution, ($AgNO_3$), quite neutral, is used to distinguish coatings, and for detecting *Chromium* and *Vanadium*.

Fuming hydriodic acid, (HI), obtained by the action of moist air on phosphorus tri-iodide. To prepare the latter, 1 part of phosphorus is dissolved in carbon di-sulphide, and gradually 12.3 parts of iodine added. This solution is now gently heated to expel most of the di-sulphide of carbon, and next placed in some cooling mixture, whence crystalline laminæ of phosphoric tri-iodide separate, which fuse at 55° C. These are put into a wide-necked, flat-bottomed glass flask, which can be tightly closed with a glass stopper. The small porcelain dishes with the adhering coatings on their surfaces may thus be placed over the flask and readily exposed to the fumes of the hydriodic acid, converting their deposits into iodine compounds. When the fuming of this reagent ceases, it is rendered active again upon the addition of some *anhydrous phosphoric acid*. These coatings may likewise be turned into iodides by saturating an asbestos-rod with an alcohol solution of iodine, firing it, and moving the flame to and fro,

beneath the coated porcelain dish. Should a brown-colored product, resulting from the separation of free iodine, condense on the porcelain dish, it may be removed by careful heating.

Ammonia, (NH_4OH), and *ammonium sulphide* (or *ammonium sulphydrate*), $(NH_4)_2S$, are employed for determining such coatings.

Bromine, (Br), kept in a wide-necked, well-closed flask, is used for exposing substances to its vapor, which, in the presence of water, acts as an oxidizing agent.

Ferrocyanide of potassium (yellow prussiate of potash), $K_4Fe(CN_6).3H_2O$, serves in solution for the recognition of *Iron*, *Copper* and *Molybdenum*.

Plumbic acetate, $Pb(C_2H_3O_2)_2$, is used for tracing *Chromium*.

Bismuthous nitrate, $Bi(NO_3)_3,5H_2O$, as reagent for *Tin*.

Acetic acid, ($C_2H_4O_2$), is employed in investigations of *Chromium*, *Vanadium*, *Manganese*, and *Uranium*.

Mercuric cyanide, $Hg(CN)_2$. Its solution is sometimes used for the detection of *Palladium*.

Hydrochloric and *nitric acids*, as well as a mixture of the two, or *aqua regia*, are quite frequently employed—the latter in testing for *gold*, *platinum*, etc.

For test operations, only very minute quantities of the substances are used. Decrepitating bodies, as already stated, are ground into very fine powder, and taken up by a moistened strip of filter paper (1 centimeter square). If this is placed between two rings of a coil made of hair-fine platinum wire and then burnt, a cohering crust remains which may be tested in the flame without any difficulty.

When substances require to be held in the flame for a long time, it is very convenient to use a Bunsen stand, which is provided with horizontal clips and arms, movable horizontally and vertically on the vertical support. The arms carry small glass tubes supporting platinum wire or asbestos fibers, and the clips are used for holding the test tubes. See p. 110.

6. Methods of Examination.

A. *Ignition of the Elements at High Temperatures.*

When heating small assays the following phenomena must be considered:—

1. The *emission of light*, which is ascertained by holding the substance on platinum wire in the *hottest* part of the zone of fusion. The emissive power is estimated as *low*, *medium* or *high*, according as the luminosity of the specimen falls below, equals, or exceeds that of the platinum wire, introduced at the same time.

2. The *fusibility*, or melting point, is expressed by a scale of temperature of the following *six grades*, distinguishable by the appearance of a thin platinum wire in different portions of the flame, viz:

a. Below red heat.
b. Incipient red heat.
c. Red heat.
d. Incipient white heat.
e. White heat.
f. Intense white heat.

3. The *volatility* is determined by the time required to volatilize a weighed bead (0.01 grm.) in the zone of fusion, and comparing it with the time required to

volatilize an equal weight of sodic chloride, the volatility of which is taken as a unit of comparison. The odor evolved, if any, must be observed.

4. *Flame coloration.*—Many volatile substances may be detected by placing the test specimen in the *upper reducing flame* at *C*, when the colorations appear in the *upper oxidizing* flame at *E*. Mixtures of flame-coloring bodies may first be tested in the coolest part of the flame base at *A*, to obtain (for a moment only) the coloration produced by the most volatile bodies, unmixed with the less volatile ones.

B. *Oxidation and Reduction of Substances.*

1. *Fused Glass Beads.*—The oxidation and reduction of fused substances are executed on platinum wire. The beads adhering to the ends of the wires are *oxidized* in the *lower oxidizing flame at G, and reduced in the lower reducing* flame at *D*.

2. *Reductions in Closed Glass Tubes.*—The completely dried test-specimen is heated together with soda and carbon (soot of turpentine is the best) or with metallic sodium, or metallic magnesium wire-clippings. The tubes made of thin glass are 3 mm. wide, and 3 cm. long. The sodium is freed from the naphtha, in which it was preserved, with blotting paper, next rolled between the fingers into a small cylinder which is placed in the tube, and surrounded by the test-specimen. The tube is now heated to its own melting-point (whereby usually a combustion takes place in the interior). The cold tube is then crushed, and the reduced material carefully collected on glazed paper for further investigation.

3. *Reduction on the Charcoal Rod.*—On the point of the small charcoal rod, already described, we place the test-specimen, of about the size of a mustard seed and previously mixed with a drop of fused sodic carbonate, into the lower oxidizing flame at *G*, for the purpose of fusion, and next pass it into the hotter portion of the lower reducing flame opposite at *D*. After the reduction has taken place, recognizable by the violent boiling up and frothing of the soda, the specimen is allowed to cool in the dark interior of the flame. The end of the charcoal rod is then nipped off, placed in an agate mortar, and ground with a few drops of water. After lixiviating the charcoal, the products of reduction are kept for further investigation.

C. *Incrustations or Coatings on Porcelain.*

The volatile elements reducible by hydrogen or carbon may either be separated as such from compounds, or as oxides, and collected upon glazed porcelain. Such deposits may next be converted into iodides, sulphides, or other combinations having characteristic qualities, by means of which they can be recognized. The incrustations or films consist in the center of a thick layer surrounded on all sides by a thinner coating passing to the merest tinge. These reactions are so sensitive that in many cases 0.01 or 0.001 mgrm. of material suffices to produce them, surpassing in delicacy Marsh's arsenic test.

The *incrustations produced* are as follows:

a. Metallic Films or Incrustations are produced by heating a very small particle of the substance placed on an asbestos fiber, in the *upper reducing flame* at *C* (not *too*

large, and perfectly free from smoke), with one hand, whilst holding at the same time in the other a thin and glazed porcelain capsule (0.1 meter in diameter), Fig. 113, filled with cold water, and placing it closely over the asbestos fiber in the upper reducing flame. The volatile metals, if present, will be deposited as a dark incrustation, either dull or lustrous. This deposit is then further examined as to its solubility in dilute nitric acid (containing 20 per cent. of anhydrous acid).

b. Oxide Incrustations.—These are formed by holding the porcelain capsule in the preceding experiment, at some distance from the test-specimens, into the upper oxidizing flame at *E*. It may then be tested—

1st, by a drop of stannous chloride; if no reduction is effected we add:—

2. Caustic soda solution until the precipitated hydrate of tin oxide is redissolved, and observe whether a reduction is the result.

3. The incrustation is touched with some drops of neutral argentic nitrate solution by means of a glass rod, spread out, and ammonia vapor blown into it.* If a precipitate is formed, the color is observed.

c. Iodide Films.—These are formed by placing the oxide incrustation on the cold capsule over the wide-mouthed glass flask containing hydriodic acid and phosphorous acid (derived from the gradual deliquescence of phosphoric tri-iodide). The iodide coating may be

* The latter is best accomplished by using a small-sized ordinary wash-bottle, in which the blowing-tube extends under the ammonia solution, and the *pointed ejection-tube* only to the lower end of the perforated cork.

A. *Table of Volatile Elements wi*

	Metallic Incrustation and Coating.	Oxide Incrustation and Coating.	Oxide Incrustat with SnC
TELLURIUM,	Black; with brown coating.	White.	Black.
SELENIUM,	Cherry-red; with brick-red coating.	White.	Brick-re
ANTIMONY,	Black; with brown coating.	White.	White.
ARSENIC,	Black; with brown coating.	White.	White.
BISMUTH,	Black; with soot-brown coating.	Yellowish-white.	White.
MERCURY,	Gray; non-coherent coating.		
THALLIUM,	Black; with brown coating.	White.	White.
LEAD,	Black; with brown coating.	Light ochre-yellow.	White.
CADMIUM,	Black; with brown coating.	Brownish-black; with white coating.	White.
ZINC,	Black; with brown coating.	White.	White.
INDIUM,	Black; with brown coating.	Yellowish-white.	White.

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R L

B. *Reducible to metals, but yielding no incrustations.*

IRON COMPOUNDS.—*Reduction on the charcoal rod* furnishes neither metallic globules nor lustrous scales; ground fine in an agate mortar the reduced mass is attracted by a magnet in the form of a black, dull brush, which, when rubbed upon paper, then touched with a drop of aqua regia and gently warmed, produces a yellow spot that turns deep blue by the addition of a drop of ferrocyanide of potassium solution. The paper ought previously be tested for iron.

Borax Bead.—Ignited in oxidizing flame with some oxide gives whilst hot, according to the quantity, a yellowish-red to brownish dark-red glass, which, on cooling, turns yellow to brownish-yellow. In reduction flame the bead is red whilst hot, and bottle-green when cold.

NICKEL COMPOUNDS.—*Reduction on the charcoal rod* furnishes white, lustrous, ductile, metallic spangles, which are attracted by the magnet. Rubbed on paper the metal yields, with a drop of nitric acid, a green solution which, when touched with a drop of caustic soda on a glass rod, thence exposed to bromine vapor, and again touched with caustic soda, furnishes a black spot of peroxide of nickel.

Borax Bead.—In the oxidizing flame dirty violet when hot; brown when cold; upper reducing flame gray from metallic nickel, which at times unites to a silver-white nickel sponge, whilst the bead turns colorless.

COBALT COMPOUNDS.—*Reduction on the charcoal rod* yields white, shiny, ductile, metallic spangles, which are attracted by the magnet. Rubbed on paper the metal furnishes, in contact with nitric acid, a red solu-

tion which, when touched with a drop of hydrochloric acid and then dried, yields a green spot which, when moistened with water, again disappears. By means of caustic soda and bromine vapor we obtain, as with nickel, a brownish-black spot of peroxide of cobalt.

Borax Bead.—Oxidizing flame and reducing flame deep blue, not reduced to metal in the bead.

PALLADIUM COMPOUNDS. *With Soda on Platinum Wire.*—In the upper oxidation flame we obtain a gray mass similar to platinum sponge which, when rubbed in an agate mortar, forms silver-white, lustrous, ductile, metallic spangles, which form a red solution with nitric acid. Adding a drop of mercury cyanide and blowing a current of ammonia vapor over the liquid, a white flaky precipitate is produced, which is redissolved by an excess of the reagent.

PLATINUM COMPOUNDS. *With Soda on Platinum Wire.*—In the upper oxidizing flame they are reduced to a spongy mass which, ground in an agate mortar, yields silver-white, shiny, ductile, spangles, insoluble in nitric or hydrochloric acid, but easily soluble in aqua regia (a mixture of both), with a light yellow color when the platinum is pure; with a brownish-yellow color, if palladium, rhodium, or iridium is present.

Mercury cyanide with a current of ammonia vapor gives no white precipitate, but a yellow crystalline one of ammonium-platinum chloride.

IRIDIUM COMPOUNDS. *With Soda on Platinum Wire.*—In the upper oxidizing flame a metallic reduction takes place; the mass ground in an agate mortar is not shining nor ductile, and is insoluble in acids, including aqua regia.

A. *Table of Volatile Elements wi*

	Metallic Incrustation and Coating.	Oxide Incrustation and Coating.	Oxide Incrustat with SnC
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ARSENIC,	Black; with brown coating.	White.	White.
BISMUTH,	Black; with soot-brown coating.	Yellowish-white.	White.
MERCURY,	Gray; non-coherent coating.		
THALLIUM,	Black; with brown coating.	White.	White.
LEAD,	Black; with brown coating.	Light ochre-yellow.	White.
CADMIUM,	Black; with brown coating.	Brownish-black; with white coating.	White.
ZINC,	Black; with brown coating.	White.	White.
INDIUM,	Black; with brown coating.	Yellowish-white.	White.

Method employed.	Reactions obtained.	Indications of:
I. We endeavor to obtain a metallic incrustation on a porcelain capsule.	An incrustation which is to be tested in regard to its solubility in dilute nitric acid, thus:	Scarcely attacked: Te, Se, Sb, As. With difficulty dissolved: Bi, Hg, T (Thallium). Instantly dissolved: Pb, Cd, Zn, I (Indium).
II. The substance is heated with addition of sodic carbonate on a charcoal rod.	*a.* A gray powder:	Magnetic: Fe, Ni, Co Non-magnetic: Pd, Pt, Rh, Ir.
	b. A metallic globule:	Cu, Sn, Ag, Au.
III. The mass, mixed with Na_2CO_3 and KNO_3 is heated on a platinum wire.	*a.* A white or colorless fusion:	Mo, W (tungsten), Ti, Ta Nb, Si.
	b. A yellow fusion:	Cr, V.
	c. A green fusion:	Mn.
IV. Special proceedings for finding: U, P, S, (described in our special methods of detection).		
V. Flame-coloration: K, Na, Li, Sr, Ba, Ca.		

Besides the characteristic flame coloring by which certain substances may be recognized, there is a large series of general flame-reactions, which may be systematized as follows: (See Table A.)

B. *Reducible to metals, but yielding no incrustations.*

IRON COMPOUNDS.—*Reduction on the charcoal rod* furnishes neither metallic globules nor lustrous scales; ground fine in an agate mortar the reduced mass is attracted by a magnet in the form of a black, dull brush, which, when rubbed upon paper, then touched with a drop of aqua regia and gently warmed, produces a yellow spot that turns deep blue by the addition of a drop of ferrocyanide of potassium solution. The paper ought previously be tested for iron.

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PLATINUM COMPOUNDS. *With Soda on Platinum Wire.*—In the upper oxidizing flame they are reduced to a spongy mass which, ground in an agate mortar, yields silver-white, shiny, ductile, spangles, insoluble in nitric or hydrochloric acid, but easily soluble in aqua regia (a mixture of both), with a light yellow color when the platinum is pure; with a brownish-yellow color, if palladium, rhodium, or iridium is present.

Mercury cyanide with a current of ammonia vapor gives no white precipitate, but a yellow crystalline one of ammonium-platinum chloride.

IRIDIUM COMPOUNDS. *With Soda on Platinum Wire.*—In the upper oxidizing flame a metallic reduction takes place; the mass ground in an agate mortar is not shining nor ductile, and is insoluble in acids, including aqua regia.

RHODIUM COMPOUNDS.—Distinguished from iridium compounds, only that the metallic powder, when fused with potassium sulphate, is partly oxidized, and forms a rose-red solution.

OSMIUM COMPOUNDS.—In the oxidizing flame osmic acid is produced, possessing a chlorine-like, pungent odor, attacking the eyes.

GOLD COMPOUNDS. *With Soda on a Charcoal Rod.*—A yellow, lustrous granule is obtained, which, in a mortar, yields golden yellow spangles. Insoluble in nitric and hydrochloric acids, but soluble in aqua regia. The light yellow solution imbibed by white blotting (filter) paper, and touched with a drop of stannous chloride ($SnCl_2$) produces a splendid purple color (purple of Cassius), used in the arts for imparting to glass a ruby color.

SILVER COMPOUNDS. *With Soda on a Charcoal Rod.*—A white, ductile globule is produced which, when heated, is dissolved in nitric acid. Hydrochloric acid throws down from the solution a white, curdy precipitate, soluble in ammonia, but insoluble in nitric acid.

COPPER COMPOUNDS. *With Soda on a Charcoal Rod.*—A copper-red, ductile globule is obtained, soluble in nitric acid with a blue color. If some of the solution is imbibed by white blotting paper, and a drop of ferrocyanide of potassium added, a brown spot is produced.

Borax Bead —The oxidizing flame furnishes a blue bead which, in the lower reduction flame, upon the addition of a little stannic oxide yields a brownish-red color of cuprous oxide (Cu_2O). By alternating the oxidizing and reducing process a ruby-red, transparent bead is obtained ; best when the reduced bead is allowed *to oxidize slowly.*

TIN COMPOUNDS. *On a Charcoal Rod.*—White, bright, ductile globule, dissolving slowly in hydrochloric acid; by nitric acid it is not dissolved, but is converted into insoluble, white, stannic oxide. In tin solutions bismuthic nitrate and an excess of caustic soda, furnish a black precipitate.

C. *Elements which can best be recognized from the reactions of their compounds.*

MOLYDBDENUM COMPOUNDS. *With Soda on the Charcoal Rod.*—Reducible with difficulty to a gray powder.

Borax Bead.—The bead in the oxidizing flame is at first colorless, but when completely saturated, forms a bluish enamel; in the reducing flame the bead becomes black or brownish-black and opaque.

Special Reactions.—The finely powdered substance is mixed with soda (best obtained by fusion of a fragment of a soda crystal), and this mixture fused within a platinum spiral of 2–3 mm. diameter exposed to the flame of a Bunsen lamp. The mass, when heated to a white heat, is knocked off and dissolved in a few drops of warm water. The clear liquid above the sediment, is imbibed by a strip of blotting paper, and submitted to the following tests: After being acidulated with hydrochloric acid, the addition of ferrocyanide of potassium produces a red brown spot. Stannous chloride, added gradually, forms at once, or after gentle heating, a blue color. Ammonium sulphide produces a brown color, and upon the addition of hydrochloric acid, a brown precipitate, whereby the paper often turns blue.

TUNGSTEN (WOLFRAMIUM) COMPOUNDS.—A fusion is produced like that described under molybdenum. The

further tested by breathing upon it (solubility), and by having ammonia vapor blown upon it.

d. Sulphide Incrustations are produced from the iodide incrustation by blowing a current of sulphide of ammonium vapor upon it, and expelling the superfluous ammonium sulphide by gently heating the porcelain capsule. The sulphide incrustation left is then further tested to examine its *solubility* in water by breathing upon it, or by adding a drop of water, and for its solubility in ammonium sulphide, either by blowing or dropping the reagent upon it.

7. General Review of Flame Reactions.

The elements which may be recognized by the flame reactions may be divided into three groups, according to their behavior during their oxidation and reduction.

A. Volatile elements, separable by reduction as incrustations (see the table of volatile elements appended hereto).

B. Reducible metals furnishing no incrustations.

C. Elements which may best be recognized from the deportment (reactions) of their compounds.

By considering, in addition, those substances recognized by their flame coloration, the following general schedule of flame reactions may be given, and their further chemical behavior, elsewhere described, may be considered and compared with it.

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With Soda on Platinum Wire.—In oxidizing flame a clear bead is produced, with strong effervescence. When this bead is treated with water and acetic acid, and the solution carefully evaporated, a gelatinous mass of hydrous silicic acid separates.

PHOSPHORUS COMPOUNDS.—The completely dried sample, mixed with an equal quantity of dry sodium carbonate, is put into a glass tube together with a few cuttings of magnesium wire, or a small piece of metallic sodium, and heated over the burner until the whole mass glows and fuses. The tube is now broken and the contents moistened with water, when the characteristic odor of phosphide of hydrogen is evolved, resembling that of rotten fish.

SULPHUR COMPOUNDS. *With Soda on the Charcoal Rod.*—In the lower reduction zone a fused mass is obtained which, when placed upon silver-foil, or a silver coin, and then moistened with a drop of water, produces a *black spot.* However, this reaction is only reliable, when the *coal gas,* used in the burner, is free from sulphur, and after the absence of selenium and tellurium has been ascertained, since these elements yield the same reaction.

Metallic sulphides show their contents of sulphur by the evolution of sulphurous acid gas (SO_2), bleaching vegetable colors, such as litmus, and having the well-known suffocating odor of burning sulphur.

CHAPTER VIII.

SPECIAL METHODS FOR DETECTING THE ELEMENTS, OR SOME OF THEIR COMBINATIONS WHEN PRESENT IN COMPLEX CHEMICAL COMPOUNDS.

ALUMINIUM. This may be traced in most of the infusible minerals by the blue color which the assay assumes when, after being strongly heated, it is moistened with cobalt solution and reheated. Very hard minerals, such as corundum, must previously be very finely pulverized. In the foregoing test a blue *infusible* mass alone indicates alumina; if any fusion takes place after adding the cobalt nitrate solution it may be due to formation of silicate of cobalt, &c.

Native crystallized alumina, such as corundum, ruby, sapphire, emery, are, like strongly ignited amorphous alumina, almost entirely insoluble in acids, but when fused with bisulphate of potassium, caustic potash or carbonate of potassium, pass into a soluble condition. The colorless aluminium salts are either insoluble or soluble in water, losing the acid upon ignition. Caustic alkalies precipitate from their solutions a gelatinous basic salt, soluble in an excess of the precipitant. From this solution aluminium is thrown down as hydrate by sal-ammoniac (or better, after the neutralization with HCl, by ammonia or carbonate of ammonium). Ammonia, carbonate of ammonium, and sulphide of ammo-

nium, precipitate gelatinous hydroxide = $Al(OH)_3$, soluble somewhat in the first, insoluble in the other reagents mentioned, *e. g.*,

$$2KAl(SO_4)_2+6NH_4OH=2AL(OH)_3+K_2SO_4+3(NH_4)_2SO_4.$$

In the presence of magnesia, the precipitate, resulting from the addition of alkalies, contains magnesia, readily separated by repeated solutions in HCl, and reprecipitation by ammonia, or preferably by boiling with sal-ammoniac solution until no ammoniacal odor can be perceived, when the magnesia passes into solution as an ammoniacal double salt.

Phosphate of soda precipitates from aluminium salts gelatinous *phosphate of aluminium*, soluble in potassium hydrate, but insoluble in acetic acid (distinction from calcium phosphate). Chloride of barium, or barium hydrate solution, removes from a solution of phosphate of aluminium in potassium hydrate, all the phosphoric acid in the form of phosphate of barium. From an alkaline solution of alumina the addition of silicate of potassium (soluble glass) produces a precipitate of silicate of aluminium, leaving in solution all the phosphoric acid.

AMMONIA. The substance is mixed with some caustic soda, potash or lime in the closed tube (a common reagent tube will answer), and the mixture heated, when ammonia gas is evolved, recognizable 1st, by its pungent odor (hartshorn); 2d, by turning moistened red litmus-paper blue; 3d, by its producing dense white fumes with the vapor of concentrated hydrochloric acid, when a glass rod, moistened with the latter, is brought

near it; 4th, by Nessler's test. The fact must not be overlooked, however, that organic nitrogenous bodies evolve ammonia as a product of decomposition, when these are heated to redness with a sufficient excess of powdered caustic potash or soda, or a mixture of caustic (burnt) lime and soda.

Ammonia may be obtained even from a nitrate salt by ignition with potash-lime, provided that a non-nitrogenous body, like sugar, be added to the mixture, but only when the latter is in great excess; *e. g.*, 1 part nitre and 40 parts sugar, has been found to be the best proportion.

Platinic chloride precipitates from ammonia solutions a yellow crystalline precipitate, insoluble in alcohol or ether. It leaves upon ignition pure, *spongy platinum*.

ANTIMONY. The ores of antimony usually afford white fumes on charcoal, or when heated on aluminium foil; the fumes are inodorous. The coating, which is plentifully deposited upon the charcoal, forms near the assay and is not very readily volatilized. It is often crystalline near the assay, being in minute octahedrons, or, immediately around the point of heating, in needles. In the open tube antimony gives a white pulverulent or crystalline sublimate of oxide, coating the glass. This sublimate is only volatilized again by strong heating. Antimony sulphides give at a strong heat in the closed tube a sublimate which is black while hot, brownish-red when cold. Treated with nitric acid, compounds of antimony deposit white metantimonic acid, $HSbO_3$.

In order to trace antimony when combined with other volatile metals, the white coating on charcoal (or better on the gypsum or porcelain tablet) is touched

with a drop of hydriodic acid,* and once more heated. If the coating consists of antimony it turns to a fine red, which disappears when exposed to strong ammonia fumes; if bismuth, to brown, which changes to scarlet on exposure to ammonia fumes; if lead, to a light yellow or yellow-green when thin; if cadmium, to white. Since these colored coatings are very distinct and different, all the metals quoted may be recognized when present together (Haanel).

When antimony is combined with lead and bismuth, it is best separated by treating the substance with fused boric acid in the O. F., when the oxides of lead and bismuth are absorbed by the boric acid, and the charcoal becomes coated with a sublimate which, when the blowing has not been too strong, consists of oxide of antimony, free from the oxides of lead and bismuth.

When antimony is combined with copper it is separated from it with difficulty, and the coating of antimony is scarcely recognizable on the charcoal. Under these circumstances the alloy is heated in the O. F. with a bead of S. Ph. until the latter has dissolved a portion of the antimony, the glass is then removed from the remaining metallic granule, placed on charcoal and heated with tin in the R. F. If the bead turns turbid and *black*, antimony is indicated. However, as bismuth gives the same reaction, it is best to separate and distinguish them in the *wet way*.

When the oxides of antimony, tin, and copper are combined together, we treat the mineral powder with a

* HI is obtained when pulverized iodine is suspended in water and a current of sulphide of hydrogen gas passed through it.

mixture of soda and borax in the R. F. on charcoal. The metallic globules are removed from the glassy mass and fused with 3 to 4 parts (by volume) of pure test-lead and *fused boric acid*, when metallic copper remains behind, while tin goes into the slag, and antimony coats the charcoal white.

Sulphides of lead and antimony are mixed with soda and treated in the R. F. on charcoal; when near the assay the yellow lead coating appears (red when hot), and beyond this the white sublimate of antimony.

Compounds of antimony are, according to Plattner, heated for a short time in the open tube, when they yield a mixture of octahedral and prismatic crystals (compare arsenic) and amorphous antimonious acid. A small amount of antimony mixed with sulphide of arsenic is detected by heating the dry mixture gently in a closed tube; the *sulphide of arsenic* volatilizes, while the *dark colored sulphide of antimony* remains where the assay was originally placed. The tube is then cut off between the two sulphides, and the dark sulphide of antimony transferred to an open tube. By applying heat the characteristic antimony reaction will appear. When the quantity is extremely small, the tube is crushed, and the fragments, with the adhering sulphides, are introduced into the open tube.

Antimony fuses at 425° C. (797° F.) and volatilizes slowly at a white heat. By fusing it in the air it takes fire, forming a dense white, inodorous vapor, consisting of antimonious oxide, Sb_2O_3. If the fuming globule be dropped on the floor it spreads, leaving white trails. Antimony is very nearly insoluble in HCl, and H_2SO_4 unless finely powdered; in aqua regia, easily soluble to

antimonious or antimonic chloride, $SbCl_3$ and $SbCl_5$. Hot sulphuric acid dissolves it, forming antimonious sulphate with evolution of SO_2. All the sulphur compounds of antimony are soluble in hot concentrated HCl, forming $SbCl_3$ with evolution of H_2S.

Sb_2O_3 is volatile at red heat, easily soluble in hydrochloric and tartaric acids, insoluble in nitric acid. Its unstable salts are decomposed with much water; a white basic salt separates, while the acid solution contains yet some of the antimonious salt, *e. g.*, $SbCl_3 + H_2O = SbOCl + 2HCl$. Tartaric acid prevents this reaction. Zinc separates from solutions of antimonious salts, except the nitrate, a black powder of metallic Sb. When a few drops of a compound of antimony, previously acidulated with HCl (nitric acid is injurious) are brought together with a little zinc upon platinum foil, the latter becomes covered with a black or brown adherent deposit. This reaction is very sensitive, and takes place even with a dilute solution, a brown spot being formed at once,* which is soluble in warm nitric acid, antimonic acid being produced.

H_2S produces in acid solutions of antimonious salts, orange-red Sb_2S_3, easily soluble in $(NH_4)_2S$, or in caustic alkali, but very slightly soluble in ammonia, and insoluble in bicarbonate of ammonium and dilute acids. Warm concentrated HCl dissolves it to $SbCl_3$, while H_2S escapes. A dilute solution of tartar emetic ($2K(SbO)C_4H_4O_6 + H_2O$) is colored orange by H_2S, but is precipitated by the addition of acid. Caustic alkalies, alkaline carbonates, as well as ammonia, and carbonate

* A characteristic difference from arsenic and tin compounds.

of ammonia, in absence of tartaric and citric acids throw down white amorphous antimonious hydroxide, $Sb(OH)_3$, soluble in caustic alkali, insoluble in ammonia.

There are two hydrogen antimoniates or acids: *metantimonic acid*, $HSbO_3$ (monobasic) and *pyro-antimonic acid* $H_4Sb_2O_7$ (dibasic), or isomeric with antimonic acid and monobasic.

The normal antimoniates, as $KSbO_3$, are all insoluble in water, except a hydrated potassium antimoniate, and this is made anhydrous and insoluble by boiling the solution.

The super-antimoniates, as $K_4Sb_2O_7$, are all insoluble in water.

The monobasic potassium meta-antimoniate, $KSbO_3$, is used as a precipitant for sodium (with all other acids soda forms *soluble salts*), and is prepared by fusing *antimonic acid* with a large excess of potassium hydrate; then dissolving, filtering, evaporating, and digesting hot the *syrupy solution*, with large excess of potassium hydrate, best in a silver dish, decanting the alkaline liquor, and stirring the residue, to granulate dry; this reagent must be kept dry, and only dissolved when required for use to precipitate soda. The reagent is of course not applicable to acid solutions.

On the insolubility of meta-antimoniate of soda rests one of the best methods for the separation of antimony from other metals, and particularly from arsenic. If any compound of antimony (except the sulphide) be intimately mixed in a porcelain crucible with four parts of nitrate of soda and two parts of anhydrous carbonate of soda, and heated until the mass becomes

entirely white, then treated, when cold, with water (or still better with very dilute alcohol), all the antimony remains as meta-antimoniate of soda, the arsenic as an *arseniate* of the alkali being found in the solution.

For the formation of, and reaction of, antimonious hydride, SbH_3, compare arsenic.

ARSENIC (*Arsenicum*). A steel-gray, lustrous, brittle, and easily pulverizable non-metallic element, vaporizing directly from the solid state at 356° C. (673° F.) in closed vessels; the vapor is colorless, with a strong *garlic odor*.

Arsenious and arsenic acids are reduced to the elementary metallic state by several methods of great analytical importance. By the action of hydrogen gas, generated from an acid solution (Marsh's test), it is reduced from all its soluble compounds when it enters into a combination with the hydrogen, to arsenious hydride, arsine, AsH_3, which is gaseous and extremely *poisonous*. The latter can be identified by numerous reactions, and from it the arsenic can again be readily obtained in its free elementary state. The hydrogen is generated by sulphuric acid diluted with 6 to 8 parts of water and zinc (both free from arsenic).

$$Zn + H_2SO_4 = ZnSO_4 + 2H.$$

The hydrogen removes the oxygen from either oxide of arsenic,* forming water, and then combines with the arsenic, two atoms of hydrogen taking the place of one atom of oxygen.

$$H_3AsO_3 + 3(Zn + H_2SO_4) = 3ZnSO_4 + 3H_2O + AsH_3$$

* Free arsenic and arsenious sulphides are not acted upon by the nascent hydrogen.

Arsenious hydride gas (arsine) burns with a somewhat luminous and slightly bluish flame (distinct from *pure hydrogen*).

If a piece of cold porcelain is held in the flame the reduction of temperature prevents the oxidation of As, which is at once deposited in dark, steel-gray spots.

Arsenious hydride is decomposed by heat alone. In passing through glass tubes, heated to incipient redness, the gas is decomposed, the arsenic adhering to the inner surface of the tube beyond the heated part, as a steel-gray mirror coating. The following reactions exhibited by these deposits will serve to distinguish *arsenic* from *antimony*.

Arsenic Spots.	Antimony Spots.
Dissolve in hypochlorite of soda, (NaClO).	Do not dissolve in hypochlorite.
Warmed with a drop of ammonium sulphide form *yellow* spots soluble in ammonium carbonate, insoluble in HCl.	Warmed with sulphide of ammonium form *orange* spots, insoluble in ammonium carbonate, soluble in HCl.
A drop of hot nitric acid dissolves them.	A drop of hot dilute nitric acid turns them white.
This clear solution mixed with a drop of solution of silver nitrate gives, when treated with vapor of ammonia (evolved from a glass rod, moistened with ammonium hydrate), a *brick-red* or a yellow color.	These white spots, treated with silver nitrate and vapor of ammonia give *no color*, but when warmed with a drop of ammonium hydrate they assume a *black color*.
With vapor of iodine the color turns yellow, by formation of arsenious iodide *readily volatile* when heated.	With vapor of iodine color more or less carmine red, by formation of antimonious iodide *not readily volatile* by heating.

Arsenic Mirror.	Antimony Mirror.
Deposited beyond the flame, the gas being decomposed at a red heat.	Deposited before or on both sides; the gas being decomposed considerably below a red heat.
By vaporization in the stream of gas arsenic escapes with a *garlic odor*.	The vapor has *no odor*.
By the *slow vaporization* of arsenic in a current of air, established in an open glass tube, containing the assay, which should be held obliquely over a lamp, a deposit of *octahedral crystals* (see Fig. 117) is obtained beyond the source of heat. Should enough As be present, a dense, white coating is deposited, which, when examined with a magnifying glass, may exhibit crystalline forms. This white sublimate of As_2O_3 is soluble in water, and the solution can be tested in the wet way.	*By vaporization* in a current of air a white amorphous coating is obtained, insoluble in water, soluble in HCl, and giving reactions for antimony.

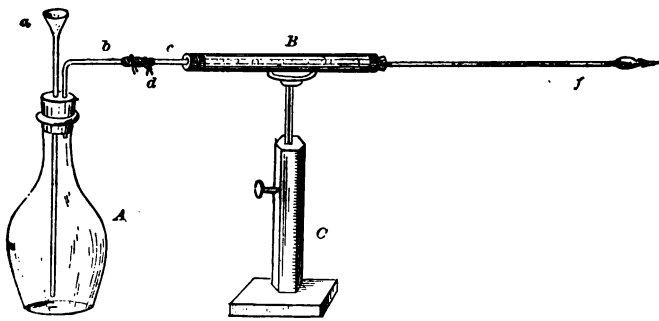
Fig. 117.

Apparatus for "Marsh's" Test above mentioned.

In Marsh's apparatus, Fig. 118, *A* is the gas evolving

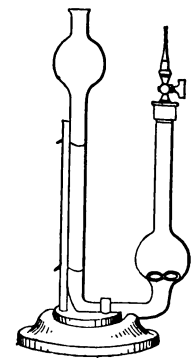
bottle, provided with funnel tube *a*, and escape tube *b*. *B* is a chloride of calcium tube supported by stand *C*.

FIG. 118.



Tube *b* is connected to *c* by India-rubber joint *d*. The gas issues at point of tube *f*, where it may be inflamed.* A simple apparatus, consisting of a test-tube provided with a cork and delivery tube, may serve in many experiments.

FIG. 119.



A convenient form of Marsh's apparatus is that shown in the drawing (Fig. 119); it consists of a bent tube having two bulbs blown upon it, fitted with a stopcock and narrow jet. Slips of zinc are put into the lower bulb, which is afterwards filled with the liquid to be examined. On replacing the stopcock, closed, the gas collects and forces the fluid into the upper

* The inexperienced experimenter is cautioned not to light the gas before all the air has escaped, otherwise an explosion, and destruction *of the apparatus* may take place.

bulb, which then acts by its hydrostatic pressure, and expels the gas through the jet as soon as the stopcock is opened. It must be borne in mind that both common zinc and sulphuric acid often contain traces of arsenic.*

Test for Arsenic in Minerals containing no Sulphur, as Whitneyite (Cu_9As).

Having had occasion to examine a mineral new to me, and of unknown composition, made up of small, angular granules having a submetallic lustre, and a yellowish-brown color, soluble in nitric acid, and free from sulphur, but containing copper, I proceeded to test for arsenic in the usual way, including Marsh's test, but without success. I found the following simple process the most accurate and delicate :† The mineral powder is placed in a large test-tube or small flask, treated with pure zinc and diluted sulphuric acid, and a piece of filtering paper, moistened with nitrate of silver solution, tied over the mouth. If arsenic be present, arsenious hydride (AsH_3) is evolved which, acting upon the nitrate of silver, will in a short time blacken it, more especially after some time standing.

Should sulphur be present in a mineral the interfer-

* Where the amount of arsenic present is small, it becomes necessary to take advantage of the effects of heat, and cause the gas to pass slowly through a red-hot tube, until all the zinc is dissolved. The reduced arsenic will be deposited on the cool part of the tube just beyond the heated portion. In all cases in using the above test, it is necessary to ascertain the purity of the zinc and acid by trial, previous to the addition of the suspected liquid.

† Qualitative Chemical Analysis, Prescott and Johnson. New York, D. Van Nostrand, 1901, p. 65.

ence of H_2S thus formed may be avoided by causing the gas to pass through cotton-wool moistened with a solution of lead acetate, and carefully placed within so as to fill the neck of the flask, then left standing for several hours. This operation may be perfectly relied upon if it gives negative results, and it is well suited for testing preliminarily the purity of the reagents employed, viz., zinc and sulphuric acid.

Arsenious and arsenic acids, and their salts, as well as the sulphides of arsenic, are examined by pulverizing and placing them in a glass bulb, covering them with six times their weight of a dry mixture of equal parts of cyanide of potassium and carbonate of soda. The mass is next gently heated, and the moisture, if any be present, removed by inserting a piece of bibulous paper. The operation is repeated until the mixture is perfectly dry. Finally, the bulb is strongly heated over an alcohol lamp, or by the blowpipe flame, when a mirror of metallic arsenic deposits in the cool part of the tube.

Very slight traces of arsenious acid can also be detected, according to Berzelius, by introducing the assay into a closed glass tube, drawn out to a small diameter (Fig. 120), and inserting a splinter of charcoal above it from *a* to *b*. The charcoal is first heated, and then the assay; the arsenious acid is reduced as it passes over the hot charcoal, and As is deposited in the form of a metallic mirror at *c*. If the tube be cut off between the mirror, *c*, and the sealed end, *a*, the mirror, upon heating, gives off the garlic-like odor of arsenic.

Closed tubes, for the reduction of arsenical compounds *and sublimation* of arsenic, should all be made

of hard German or Bohemian glass, free from reducible metals.

They are usually about three inches long. Fig. 121 represents the forms mostly used for this purpose, and

Fig. 120.

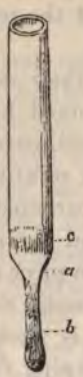


Fig. 121.

which the student may readily prepare for himself from glass tubing of suitable diameter with the aid of the Bunsen blast-burner.

Reinsch's test is founded upon the fact that metallic copper reduces arsenious acid from a hot hydrochloric acid solution.

A bright slip of copper foil is boiled in the liquid previously acidulated with hydrochloric acid; the copper withdraws the arsenic and becomes covered with a white alloy. By heating the metal in a glass tube the arsenic is expelled and oxidized to arsenious acid.

Barium.—All salts of barium, except silicates and phosphates, yield the characteristic yellowish-green col-

oration of the flame, especially after moistening with HCl. Even the insoluble sulphate $BaSO_4$ (heavy spar), obtained when any soluble mineral containing barium is dissolved in HCl, and the solution precipitated by dilute sulphuric acid, causes the same coloration. When observed through green glass (colored with oxide of copper) the barium flame appears bluish-green. See flame coloration, page 115.

Strontium may interfere with the barium reaction. The presence of sulphate of barium with the sulphate of strontium often shows in the flame, on first heating, or it can be detected by fusing the mixture with 3 or 4 parts of chloride of calcium in a platinum spoon, and boiling the fused mass with water. If a cloudiness is produced by adding to the clear dilute solution a few drops of chromate of potassium, the presence of barium is indicated. Strontium is only precipitated from the concentrated solution (Chapman).

Beryllium.—(Beryllia, oxide of beryllium), BeO, is found in a few minerals, *e. g.*, *phenacite*, *beryl*, *euclase*. It gives no characteristic reaction B. B. With borax on platinum wire it is soluble in large quantities in a clear glass, that becomes milk-white by flaming, or, when saturated, by simple cooling. With salt of phosphorus it behaves as with borax. With solution of cobalt in O. F. it acquires a pale bluish-green color.

The wet reactions bear a close resemblance to those of aluminium; it differs, however, from the latter by its solubility in carbonated alkalies and in boiling sal-ammoniac solution, with evolution of ammonia; by its salts affording no precipitate of beryllium alum with sulphate of potassium, and by the fact that its dilute

solution in the caustic alkalies is decomposed by long boiling, the earth being precipitated. Alkaline carbonates throw down in solutions of its salts $BeCO_3$, soluble only in considerable excess of the precipitant. A concentrated solution of carbonate of ammonia dissolves the precipitate more readily than either the carbonate of sodium or potassium; but by boiling the earth is again precipitated in such a solution. Native minerals containing beryllia are fused with 4 parts of alkali carbonate. The mass is evaporated with a slight excess of sulphuric acid to dryness, and the SiO_2 separated by the addition of water. From the concentrated filtrate nearly the whole amount of alumina may be removed in the form of *alum*, while all the BeO remains dissolved in the mother-liquor. This solution is poured into a warm concentrated solution of carbonate of ammonium. After standing for several days, the solution, containing $BeCO_3$, is filtered off and boiled for a long time to precipitate the $BeCO_3$; or it may, after being acidulated with HCl, be thrown down by ammonia as beryllium hydroxide $Be(OH)_2$.

Beryllium occurs in minerals usually in combination with *silica* and *alumina*.

Bismuth.—Fuses and gives off inodorous fumes. When treated alone or with soda in the R. F. on charcoal, it produces a dark-brown oxide, which turns pale-yellow on cooling. If a compound of bismuth be treated with a mixture of equal parts of iodide of potassium and flowers of sulphur, and fused B. B. on charcoal, a beautiful red sublimate of iodide of bismuth will be deposited (von Kobell). Compounds containing lead treated in the same manner yield a yellow to

parrot-green coating; their presence does not interfere with the reaction for bismuth.

Bismuth is nearly insoluble in HCl, but easily soluble in nitric acid or aqua regia, forming a nitrate $Bi(NO_2)_3$, or a chloride $BiCl_3$ also soluble in hot sulphuric acid, producing a sulphate $Bi_2(SO_4)_3$.

The oxide of bismuth, Bi_2O_3, is formed by strong ignition of the metal in the air, or by heating the nitrate salt. The salts are colorless; their solutions, if there be not too much acid present, are decomposed by water, and a white basic salt is precipitated. The acid which has been set free always holds some oxide in solution,

$$Bi(NO_3)_3 + H_2O = Bi(OH)_2NO_3 + 2HNO_3.$$

The decomposition of the chloride is more complete,

$$BiCl_3 + H_2O = BiOCl + 2HCl.$$

In examining small quantities of a substance for minute amounts of bismuth, the HCl solution is evaporated to a few drops, and these thrown into water. The white precipitate is insoluble in tartaric acid or tartrate of potassa; this distinguishes it from the oxide of antimony, which is soluble. H_2S and $(NH_4)_2S$ precipitate brown sulphide, (Bi_2S_3), insoluble in an excess of sulphide of ammonium. Ammonia and caustic alkali throw down white hydroxide, BiO(OH), insoluble in an excess. Chromate of potassium throws down yellow chromate of bismuth. If into a clear solution of stannous chloride in an excess of potassa we drop a solution of a bismuth salt, a black precipitate falls which is bismuth monoxide, BiO.

Boric (boracic) acid is recognized by the intense green color it or its compounds, especially silicates,

impart to the flame at the instant of fusion, when melted with three parts of the flux, called "*Turner's reagent*" (a mixture of two parts of fluor-spar and one of bisulphate of potassium). A mixture of this reagent and the substance to be tested made to a paste with water is taken upon the loop of a platinum wire and carefully introduced into the flame. The trial should be made in a dark place, or against a dark background.

Borate of sodium alone tinges the flame pure yellow, but if it be moistened with H_2SO_4, boric acid is set free, tinging its mixture with alcohol, when burned, lively green.

Another very dilicate and reliable reaction is that of Iles. The finely pulverized mineral is moistened with H_2SO_4 on platinum foil, the excess of acid evaporated at a gentle heat, and the residue worked into a paste with glycerine, which, when brought on a platinum wire into the flame colors it *yellowish-green*. Compounds of boric acid with an alkali, or an alkaline earth, are tested with turmeric paper as follows: The compound is dissolved in dilute HCl (until blue litmus is reddened by it); a strip of turmeric paper is then for some time half immersed in the solution, and then dried in a watch glass at a gentle heat (not over 100° C. or 212° F.). If boric acid is present, the immersed portion of the paper assumes a brownish-red color* (Rose).

If this brownish-red turmeric paper is treated with some alkali or alkaline carbonate, it turns to a bluish

* This color must not be mistaken for the blackish-brown shade produced by concentrated HCl. If the solution is allowed to evaporate through the paper, the upper edge of the paper becomes *scarlet*.

or greenish-black; hydrochloric acid restores the original color.

If alcohol is poured over a borate, with the addition of a sufficient quantity of concentrated sulphuric acid to liberate the boric acid, and the alcohol be ignited, the flame appears distinctly green, especially upon stirring with a glass rod and after heating the alcoholic mixture.

BROMINE.—When bromides are added to a bead of S. Ph., which has previously been saturated with oxide of copper, and is exposed, B. B., to the point of the blue flame, the bead is surrounded with a beautiful greenish-blue color on the edges. (Chlorine acts, however, similarly.)

If a bromide is fused in a mattrass with bisulphite of potassium, red bromine vapor is set free, which may also be recognized by its characteristic odor. (Berzelius.) If moistened starch-paper is exposed to this vapor, yellow bromide of starch is formed.

The method proposed by Goldschmidt for the detection of a bromine compound alone, or in the presence of iodine and chlorine, is as follows: If a bromine compound is fused in an open glass tube with pulverized bismuth sulphide (made by fusing metallic bismuth with sulphur), a yellow sublimate is formed. An iodine compound treated in the same way forms a red sublimate, and a chlorine compound a white one. With a little care these elements can be readily recognized in the presence of one another.

CADMIUM.—The pulverized substance for examination is heated B. B. in the R. F. on charcoal whereby the metal is oxidized to a reddish-yellow oxide, which *being volatile coats* the coal reddish-yellow.

To detect a minute amount of cadmium (one per cent. or even less, found in zinc or its ores), the assay powder is mixed with soda and for a short time heated B. B. in the R. F. on charcoal, when the latter is coated near the assay with reddish-brown oxide of cadmium. The zinc being less volatile forms a white coating only after continued blowing.

Caustic potash throws down from solutions of cadmium salts a white precipitate of hydrated oxide, $Cd(OH)_2$, insoluble in an excess.

Alkaline carbonates, also carbonate of ammonia, throw down the white carbonate of cadmium, $CdCO_3$, not soluble in excess. In the presence of free ammonia no precipitation takes place. Cyanide of potassium dissolves the precipitate and gives, with salts of cadmium, a white precipitate soluble in an excess, whereby a double salt (K_2CdCy_4) is formed, from which hydrogen sulphide precipitates yellow sulphide of cadmium.

Hydrogen sulphide and ammonium sulphide precipitate yellow sulphide of cadmium from saline solutions, easily soluble in acids. An acid solution, therefore, must be greatly diluted before it is acted upon by H_2S. Sulphide of cadmium is insoluble in cyanide of potassium, while sulphide of copper is soluble. Hence, in order to separate these two metals, qualitatively as well as quantitatively, their solution is precipitated by KCN, and redissolved in an excess of the reagent. By conducting a current of H_2S into their joint solution yellow sulphide of cadmium falls, while the copper remains in solution, and can only be recovered by decomposition of the cyanide of copper by means of concentrated sulphuric acid added until no more hydro-

cyanic acid escapes. From the resulting solution of sulphate of copper, black oxide of copper is precipitated by caustic potash at a boiling heat.

CAESIUM.—This rare alkali metal closely resembles potassium. It may be distinguished by means of the spectroscope. In the flame its chloride gives a violet color similar to potassium, but seen in the spectroscope two very strong lines in the blue characterize the metal.

CALCIUM, B. B.—It imparts a yellowish-red color to the flame. When observed through copper-green glass the calcium flame appears siskin-green; with cobalt-blue glass it is pale greenish-gray.

Many calcium salts give an alkaline reaction with test papers after ignition (caustic lime).

Calcium hydrate $Ca(OH)_2$ is soluble in 600 to 700 parts of cold water (lime-water), which reacts alkaline and becomes turbid in the air $(CaCO)_3$. Sulphate of calcium, $CaSO_4 + 2H_2O$, is soluble in 500 parts of water, more readily in acids, but insoluble in alcohol. When sulphate of calcium is digested, even in the cold, with carbonate of potassium or carbonate of ammonium, it is entirely converted into carbonate of calcium. Oxalic acid, or soluble oxalates, precipitate calcium completely, even from very dilute solutions, as *calcium oxalate*, $CaC_2O_4 + 2H_2O$. Ammonia promotes the formation of the precipitate, which is insoluble in water, acetic and oxalic acids, but easily soluble in mineral acids, and in neutral *magnesium salts*. From solutions previously warmed, we precipitate calcium generally by oxalate of ammonium and ammonium hydrate (the liquid must smell of free ammonia), and let it rest for twelve hours in a covered glass beaker, decant the clear

supernatant liquid, and bring the rest upon a filter, and wash with hot water containing ammonia. Limestones are tested for strontium by calcining, then adding water and boiling, when all the strontium and some little calcium will be found in the filtrate. Compare the whole group of *alkaline earths* (Ba, Sr, Ca, Mg) and note the distinctive reactions.

CARBON.—It is found in a free state and crystallized in the form of diamond and graphite. In the ordinary charcoal, in anthracite, soot, etc., the carbon is amorphous; with oxygen it forms mainly two compounds which we shall briefly consider.

1. *Carbon monoxide* (Carbonic Oxide), CO.—A colorless gas, burning in the air, with a blue characteristic flame, to *carbonic anhydride*, CO_2. It is a poisonous gas resulting from incomplete combustion. We obtain it by conducting carbonic anhydride (CO_2) over ignited coal, and also by heating many organic compounds, *e. g.: oxalic acid*, with concentrated sulphuric acid—

1. $C_2H_2O_4 + H_2SO_4 = H_2SO_4 + H_2O + CO_2 + CO$.

It combines in direct sunlight with chlorine at the ordinary temperature to a compound—carbonyl chloride, $COCl_2$—having a characteristic suffocating odor.

Most organic acids, except oxalic and formic acids, leave, after ignition, carbon behind.

CO gas is very slightly soluble in water, but is readily absorbed in a solution of *cuprous chloride in hydrochloric acid*. An unstable compound, $Cu_2Cl_2CO + 2H_2O$, is formed, which by boiling, indeed by mere dilution with water, is decomposed, and CO set free.

Carbon Dioxide (Carbonic Anhydride) CO_2.—It is soluble in water, the solution turning blue litmus paper *to a dark red.*

Carbon dioxide renders a solution of caustic lime turbid, forming insoluble carbonate of lime, and yields no hydrate. It is a feeble acid, and many metals like aluminium, etc., form no carbonates. Only the carbonates of the alkalies are soluble in water.

Fused with saltpetre carbon deflagrates, carbonate of potassium being thereby produced. Carbonates effervesce when treated with a drop or two of dilute hydrochloric acid, etc.; a few kinds require previous pulverization, and in some cases even heat must be applied before effervescence takes place.

Some carbonates (lime, etc.) lose their carbonic anhydride by simple heating in the closed tube.

CERIUM is found in the mineral cerite $(CaFe)(CeO)Ce_2(OH)_3(SiO_3)_3$ and in a number of other minerals; the Ce being replaced in part by La and Di. Cerite may be decomposed by hydrochloric acid, aqua regia, and sulphuric acid, but more completely by fusion with carbonate of soda. If the finely-powdered mineral be heated along with sulphuric acid, a few drops of nitric acid being added, and then cold water be poured on it, the sulphate of the above oxides of cerite will be dissolved out and the silicic acid be left behind. A hot saturated solution of sulphate of potassium in a moderately dilute solution of cerite precipitates the three oxides as double salts, which, after being washed with a saturated solution of sulphate of potassium, and dissolved in boiling water, containing some hydrochloric acid, are precipitated while warm by excess of potassa.

By repeated treatment of the mixture of these oxides with strong potassa lye and chlorine gas the cerium passes into yellow insoluble proto-sesquioxide, Ce_2O_3.

while lanthanium and didymium remain in solution as chlorides. Oxides of cerium give a reddish-yellow color to the borax and salt of phosphorus beads O. F., when hot, becoming paler on cooling and colorless in R. F.

The *protoxide of cerium* (CeO) is bluish-gray, the hydroxide, $Ce(OH)_2$, colorless. The former quickly passes, on ignition, into Ce_2O_4, which is yellowish-white, and when heated orange-yellow. It is soluble in sulphuric (but not in hydrochloric or nitric) acid to a yellow-colored solution. Ceroxide, Ce_2O_3, is reddish-yellow, soluble in hot concentrated sulphuric acid to a yellow-colored solution; decomposable by concentrated HCl, with addition of alcohol, with production of chlorine.

CHLORINE.—Chlorides like bromides may be detected, B. B., by adding a small portion of them to a bead of S. Ph., which has previously been saturated with oxide of copper; the bead is at once surrounded with an intensely blue flame without the green tinge observed with bromides. The presence of chlorine may also be detected by the blue color which it causes on a paper moistened with a solution of potassium iodide and starch paste. An excess of chlorine removes the color again. Bromine, ozone, nitrous fumes, etc., produce, however, the same effect.

If a metallic chloride is mixed with solid potassium bichromate and concentrated sulphuric acid in a small glass vial, a bright brownish-red gas of chloro-chromic acid is given off, condensing to drops of a like color. Ammonia turns them yellow.

Soluble chlorides placed upon a piece of clean silver, along with a fragment of sulphate of copper or sulphate

of iron, produce at once a black stain on the silver. Insoluble chlorides must previously be melted, together with soda, on a platinum wire to produce this reaction. Bromides yield the same reaction.

Nitrate of silver produces, even in very dilute solution of hydrochloric acid or metallic chlorides, a white curdy precipitate of chloride of silver, turning dark when exposed to sunlight.

CHROMIUM (B. B.).—Chromic oxide and chromic salts dissolve in beads of S. Ph., in both the O. F. and R. F., with a dirty-green tint while hot, becoming emerald-green when cold. In the borax bead O. F. with light saturation, the color is yellow when hot and pale emerald-green on cooling; with stronger saturation, the bead is red when hot, yellow emerald-green on cooling. In R. F. the bead is strong emerald-green, hot and cold. Chromium must not be confounded with vanadium, which gives similar reactions in the R. F., but differs by yielding a yellow bead with S. Ph. in the O. F.

Minerals containing but little oxide of chromium, associated with other metals (Fe, Cu, etc.) which color the fluxes, are best treated by fusing on platinum wire, or in a platinum spoon, with a mixture of equal parts of soda and niter in the O. F., whereby alkali chromate is formed. The fused mass is dissolved in water, and the yellow solution poured off from the residue; to this solution a few drops of acetic acid, and afterwards, a crystal of acetate of lead (sugar of lead), are added, when an orange-colored precipitate of chromate of lead is formed. This may be collected on a filter, washed, and tested with Bx. and S. Ph. A silicate which contains a small trace of chromium besides iron, and is not

decomposed by niter, is fused upon charcoal in the O. F. with one part of soda and one-half part of borax to a clear bead; this is pulverized, dissolved in HCl, evaporated to dryness, and dissolved in water, and the residue of SiO_2 filtered off; the protochloride of iron is changed to sesquichloride by boiling with a few drops of nitric acid, and the chromium, alumina, iron, etc., precipitated with ammonia. The precipitate is filtered off, washed, and tested as above.

The *sesquioxide of chromium*, Cr_2O_3, is a green powder which, after ignition, is insoluble in acids. The chromates are green or violet, partly soluble in water, partly only in acids. Ammonia produces a bluish-green or greenish-gray hydrate (chromhydroxide), $Cr(OH)_3$, which is slightly soluble in excess of the reagent, but reprecipitates completely on boiling.

Caustic potassa or *soda* likewise precipitates the hydrated sesquioxide, readily soluble in excess, furnishing a green color. If this alkaline solution is boiled for some time the sesquioxide is reprecipitated, and the supernatant liquid becomes colorless.

Alkaline carbonates, as well as sulphide of ammonium, throw down also hydroxide or a basic salt. In the presence of magnesium, zinc, or lead salts, the precipitate with alkalies has the formula MCr_2O_4.

If the green solution of Cr_2O_3 in caustic alkali is boiled with some peroxide of lead, chromic acid, CrO_3 is formed and the solution turns yellow; the filtrate, when acidulated with acetic acid or neutralized with nitric acid, separates yellow chromate of lead.

The Cr_2O_3, insoluble in acid becomes soluble by fusion with bisulphate of potassium; by fusion with

carbonate and nitrate of an alkali mixed together it becomes converted into a soluble chromate of the alkali. This deportment is made use of in searching for the Cr_2O_3 in insoluble compounds, and for its separation from oxides like magnesia, alumina, and sesquioxide of iron, which, undergoing no further oxidation, remain undissolved in the alkaline liquid.

Chromic acid, CrO_3, is known only as an anhydride, forming scarlet-red, deliquescent crystals. Its salts are red, like, for instance, the acid potassium salt, $K_2Cr_2O_7$, or yellow, like the neutral potassium salt, K_2CrO_4. The alkaline salts and those of the alkaline earths are both soluble in water; nearly all the other salts are either insoluble, or with difficulty soluble, in water.

Chloride of barium precipitates from soluble chromates yellow $BaCrO_4$; lead salts throw down a yellow precipitate, $PbCrO_4$; salts of bismuth produce a yellow, nitrate of silver, a purple-red, and mercurous salts a brick-red precipitate. All these precipitates are soluble in dilute nitric acid except chromate of lead, which is soluble in potassa, and can be thrown down again by acids.

Chromic acid is reduced to green sesquioxide by H_2S,SO_2, by alcohol and sugar (in the presence of a free acid), by oxalic and tartaric acids, and by any metal which (like zinc) disengages hydrogen with acids.

COBALT may generally be recognized B. B. by the blue bead it affords with Bx. and S. Ph. in both flames. It should be noted that the Bx. bead is sapphire blue, while the S. Ph. bead is purplish. This color will, however, be modified by the presence of other metals. Thus, if iron be present the bead will appear green while hot, and blue when cold. The sulphides should

be roasted on charcoal before testing for cobalt with Bx. on the platinum wire.

Cobalt forms two well-marked oxides, both of which represent bases in corresponding classes of salts: *Cobaltous* and *cobaltic* salts.

Cobaltous oxide (*protoxide*), CoO, is an olive-green powder, or, when in the condition of a hydrate, $Co(HO)_2$, rose-red; its salts are generally blue when anhydrous, or in solution containing free concentrated acids, though their aqueous solutions are pink.

H_2S and $(NH_4)_2S$ precipitate black CoS, quite insoluble in $(NH_4)_2S$; once formed it is with great difficulty soluble in *dilute nitric*, *sulphuric*, and *acetic acids*. A solution of a salt of cobalt when previously mixed with some acetate of sodium and warmed, is more readily and completely precipitated by H_2S than a salt of nickel under like circumstances (separation of Co and nickel from manganese).

Ammonia produces, in acid solutions of cobaltous salts, or in solutions containing ammonium salts, only a red color, which soon passes into brown, the slight precipitate first formed being immediately redissolved. *Caustic potash* throws down all the cobalt as a blue *basic salt*, which, by exclusion of air (and quickly by heating), passes into *rose-red cobaltous hydrate* $Co(OH)_2$, and this in the air turns to olive-green *cobaltous cobaltic hydrate*.

Alkaline carbonates precipitate peach-blossom red basic carbonate, which is readily soluble in excess of *carbonate of ammonium*, retaining the same color, but only slightly *soluble in the carbonate of sodium* and potassa. *Ferrocyanide of potassium* produces a green; ferricyanide

potassium a brownish-red precipitate. If to a neutral solution of a cobaltous salt we add *nitrite of potassium* in excess; and next, acetic or dilute nitric acid, a yellow, crystalline precipitate, $3KNO_2.Co(NO_2)_3.H_2O$, is thrown down, containing nearly all the cobalt. The precipitate is with difficulty soluble in cold water; insoluble in potassium salts, and in alcohol of 80 per cent.

Cobaltic oxide, peroxide of cobalt, Co_2O_3. It yields salts, while the corresponding Ni_2O_3 cannot form any, and attempts to produce them yield protoxide salts.

To detect nickel when together with cobalt we proceed thus: The solution, which must contain these two metals only, is freely acidulated with a few drops of HCl, cyanide of potassium is added in excess, and it is heated to boiling; if now, upon addition of dilute HCl or H_2SO_4, a precipitate follows, nickel is present.

COPPER.—It is easily detected by the green color which most copper compounds impart to the blowpipe flame, which becomes azure-blue if the substance is moistened with a drop of HCl. In the borax bead copper is in O. F. green when hot, and blue when cold; in R. F. with weak saturation the bead becomes colorless, but with strong saturation it is red opaque, or with reduced copper flakes. In the salt of phosphorus bead the colors in O. F. are the same, but with strong saturation in R. F. the bead becomes on cooling of a submetallic gray or reddish, due to formation of phosphide of copper. It is not readily reduced to the metal in S. Ph. The production of a red bead with salt of phosphorus in R. F. is rendered more certain by the treatment of the bead on charcoal with a small amount of tinfoil, when sometimes a transparent red is obtained, especially *if the reduced bead* is allowed to oxidize again slowly.

Copper may also be detected by saturating a salt of phosphorus bead with the substance containing it, and adding common kitchen salt (NaCl), when the bead will color the flame beautifully blue, owing to the formation of chloride of copper. Many minerals give this reaction by simply moistening with HCl, and exposing them in the platinum forceps to the flame. Silicates should first be pulverized, moistened with HCl, and evaporated to dryness in a porcelain capsule, then made into a paste with water and heated on platinum wire, when the blue color is imparted to the R. F. Sulphides of copper are first roasted on charcoal and then examined with a drop of HCl.

Cuprous oxide, Cu_2O, is red when anhydrous, orange as hydroxide, $Cu_2(OH)_2$. Cuprous salts are nearly or quite insoluble in water. HCl forms white cuprous chloride, Cu_2Cl_2, little soluble in water, but readily soluble in HCl. Its nearly colorless solutions, in acids and in ammonia, rapidly change, in the air, into blue or green cupric compounds.

Cupric oxide, CuO, is black when anhydrous, greenish-blue as hydroxide, $Cu(OH)_2$, insoluble in water, soluble in nearly all acids. Its anhydrous salts are nearly white, the hydrates green or blue. H_2S and $(NH_4)_2S$ precipitate from solutions black sulphide of copper, soluble in cyanide of potassium. In the cold, caustic potash throws down greenish-blue hydrate, at a boiling heat, *black basic hydroxide*. Ammonia precipitates at first a green basic salt, next blue hydrate, which, with an excess of the precipitant, form a beautiful azure-blue solution. Iodide of potassium precipitates, in the pres*ence of* SO_2, or ferrous salts, all the copper as white Cu_2I_2,

soluble in *hyposulphite of soda*, and in ammonia, in the air. Ferrocyanide of potassium precipitates brownish-red ferrocyanide of copper, $Cu_2Fe(CN)_6$, insoluble in HCl, soluble in NH_4OH. In solutions, acidulated with HCl, iron and zinc precipitate metallic *copper*. If a solution of copper is put into a platinum dish, a little HCl and a piece of zinc added, red metallic copper is thrown down, visible even in a state of great dilution. Nitric acid is the best solvent of the metal or its compounds, cupric nitrate, $Cu(NO_3)_2$, being formed. The solution in hot sulphuric acid contains $CuSO_4$, that in *aqua regia*, $CuCl_2$.

Didymium,* Di.—It is trivalent. Sesquioxide of didymium, Di_2O_3. Didymium chloride, $DiCl_3$. Didymium hydroxide, $Di(OH)_3$. Potassium hydrate, or sodium hydrate, throws down, from solution of the salts, a white bulky precipitate of $Di(OH)_3$, not soluble in an excess. Ammonia shows the same behavior, but the precipitate is soluble in a hot solution of sal ammoniac. B. B., with borax, the sesquioxide yields in both flames a colorless, or in large quantities, an amethyst colored, glass. Phosphorus salt dissolves it in the R. F. to an amethystine colored, rather violet, bead. Carbonate of sodium yields in the O. F. a grayish colored mass (distinction from manganese). Didymium is found in the minerals cerite, monazite, gadolinite, fluocerite, orthite, euxenite, etc.

Solutions of didymium salts, when concentrated, have a reddish or faint violet color and exhibit a well-marked

*This is now known to be two elements, Praseodymium and Neodymium, see Table of Atomic Weights in Appendix.

absorption-spectrum, containing two black lines, inclosing a very bright space. One of these black lines is in the yellow, immediately following Frauenhofer's line "D," the other is situated between "E" and *b*. These characters can be distinctly recognized in a solution half an inch deep, containing only 0.01 per cent. of didymium salt. Lanthanum salts do not exhibit an absorption-spectrum.

ERBIUM.—Its oxide, ErO, obtained by ignition of erbium nitrate or oxalate, has a faint rose color. It does not melt at the strongest white heat, but aggregates to a spongy mass glowing with an intense *green* light, which, when examined by the spectroscope, exhibits a *continuous spectrum* intersected by a number of bright bands. Solutions of erbium salts, on the other hand, give an absorption-spectrum, exhibiting dark bands, and *the points of maximum intensity of the light bands in the emission-spectrum coincide exactly in position with the lines of greatest darkness in the absorption-spectrum.* The position of these bands is totally different from those in the emission and absorption-spectra of didymium (Bahr and Bunsen).

FLUORINE.—When fluorides are heated in a glass tube with 4 parts of bisulphate of potassium, hydrofluoric acid is given off. This imparts to red Brazil-wood paper a straw-yellow color, and etches the tube immediately above the assay, which is especially visible after cleansing and drying of the tube.

The best method for the detection of fluorine, even when present in minute quantities, is to heat the assay with previously fused salt of phosphorus (both finely pulverized) in an open glass tube in such a manner that

the flame passes into the end of the tube. The latter is thereby rendered opaque where the hydrofluoric acid formed is condensed. This acid is further recognized by its pungent odor.

Hydrofluoric acid, HF, and *fluorides*. Concentrated HF gives off fumes in the air which are greedily absorbed by water. The aqueous solution dissolves many metals and metallic oxides, forming fluorides. Gold and platinum are not attacked, lead only with difficulty. HF has the distinguishing property of dissolving with great facility, silica or silicates not affected by other acids forming SiF_4. Certain basic silicates however resist even the action of HF. Upon this property depends the decomposition of silicates, the etching of glass, and its detection. All metallic fluorides are decomposed by concentrated sulphuric acid with evolution of hydrofluoric acid, *e. g.*, $CaF_2 + H_2SO_4 = CaSO_4 + 2HF$.

GALLIUM.—A very rare element that has been detected in some sphalerite. Only to be recognized by its spark spectrum.

GERMANIUM. A very rare element that has been found in some euxenite, in argyrodite and canfieldite. Germanium gives a coating on charcoal, white near the assay, but, on continued heating, moving out and becoming lemon-yellow to greenish. Examined with a lens the part near the assay will show white fused globules of oxide, while the coating farther from the assay looks smooth and glazed.

GOLD may generally be recognized by its physical characters: Color, luster, malleability, specific gravity. When a gold compound is heated on a carbonized match in R. F., a yellow malleable bead is obtained, which

dissolves in aqua regia. If this solution be dropped on filter paper and one drop of stannous chloride added, a purple-red color is observed. Gold can readily be detected in its solutions, inasmuch as it is obtained in the metallic state by reducing agents, the well-washed precipitate being dissolved and tested with stannous chloride. It is separated from the easily volatile metals by simple heating on charcoal in O. F. If associated with copper or silver, it must be fused with a large excess of pure metallic lead and subjected to cupellation. The copper is absorbed into the cupel with the lead as oxides, while the silver remains alloyed with the gold. If the globule is quite yellow, it is a proof that but little silver is present; it is then to be tested with salt of phosphorus, to prove the presence of silver, which after fusion on charcoal in O. F., will impart an *opaline* character to the *cool bead*. If it be more of a silver-white color, the amount of gold will be small, and in order to prove its presence and approximate quantity, the globule must be digested in a porcelain capsule with diluted nitric acid, and application of heat. The silver is thus dissolved, and the gold remains as a dark powder or as a spongy mass. If this powder be washed and fused with borax on charcoal, it will yield a globule of metallic gold. In testing ores for gold it is often necessary to pan or wash the lighter parts away and then test the concentrate. In this way several pounds of the ore may be concentrated into less than a gramme. If this is done with a little mercury (5 or 6 gms.), and the mercury be then distilled in a glass tube, the residue containing the gold may be fused to a button with a little borax on charcoal.

HYDROGEN.—This element occurs combined with oxygen as water, and in minerals as water of crystallization and as hydroxyl (OH). Water is generally detected in minerals by heating fragments (not powder) in a glass tube, about 4 or 5 inches long, closed at one end. The water given off collects in drops in the cool part of the tube, and may be tested for acids and alkalies with test-paper.

INDIUM.—This very rare metal has been detected in sphalerite. Its compounds impart a deep blue color to the flame. It is easily recognized by the spectroscope.

IODINE.—Iodides added to a bead of salt of phosphorus previously saturated with oxide of copper, tinge the O. F. intensely emerald-green. Compare Bromine and Chlorine, pages 145 and 150.

Iodides, like bromides, are decomposed by fusion with bisulphate of potassium, and yield free iodine, which may be recognized by its purple-colored vapor and disagreeable odor. If an iodide be decomposed in a test-tube with sulphuric acid in presence of chloroform or carbon bisulphide, the iodine liberated colors the chloroform or carbon bisulphide violet-red.

When an emulsion of starch paste is mixed with a little iodide of potassium, and some HCl is added, *iodine* is liberated, which colors the starch *blue.*

The *iodide of silver*, and the iodides of the alkalies, are distinguished, in the presence of other halogen compounds, by the fine scarlet coating they produce, B. B., on charcoal, when fused with *sulphide of bismuth* (obtained by heating flowers of sulphur and bismuth.

IRIDIUM, Ir.—The metal itself is easily distinguished from all others, excepting rhodium and ruthenium, by

its insolubility in acids, not being attacked in the compact state by any acid whatever, and in a state of fine division, only very slowly by nitro-hydrochloric acid. Its infusibility, even in an ordinary oxyhydrogen blowpipe flame, serves also to distinguish it from all other metals, except rhodium, ruthenium, and osmium. It may be distinguished from rhodium by fusing it, in the finely divided state, with bisulphate of potassium. The iridium is then converted into sesquioxide, but does not dissolve in the bisulphate, or color it pink-red as rhodium does.

Another method of distinguishing iridium from rhodium, and likewise from ruthenium, is to mix it intimately with potassium or sodium chloride, heat the mixture in a stream of chlorine, and dissolve the resulting double chlorides in water. Iridium thus treated yields a blackish-brown solution, rhodium a rose-red, and ruthenium an orange-yellow, solution. All compounds of Ir are easily reduced to the metallic state by ignition in an atmosphere of hydrogen; the reduced metal may then be tested in the manner just described.

Iron, Fe.—Oxides of iron impart to the borax bead, in O. F., a brownish-red color which fades to colorless or pale yellow when cold; in R. F. bottle-green when hot, paler on cooling. In the salt of phosphorus bead the colors in O. F. are similar to those with borax; in R. F. reddish when hot to nearly colorless when cold; with strong saturation in R. F. somewhat reddish when cold, or after long reduction a pale violet.

Ferrous oxide, FeO. The salts of this oxide are formed by dissolving metallic iron in dilute HCl or H_2SO_4, with evolution of hydrogen gas. In warm HNO_3 iron is oxi-

dized to a *ferric* salt. The *ferrous* salts are white when anhydrous; pale green as hydrates. They oxidize gradually on exposure to the air, forming a yellow basic ferric salt, which is deposited in a neutral solution. They give up their volatile acids at a red heat, when red sesquioxide is left behind.

Caustic alkalies and ammonia precipitate from ferrous salts white hydrated ferrous oxide, $Fe(OH)_2$, which turns green, and finally brown in the air. In the presence of ammonia-salts, or organic acids, the precipitation is incomplete.

Hydrogen sulphide gives no precipitate in acid solutions of ferrous salts.*

Sulphide of ammonium throws down the iron completely as black sulphide, FeS, only slightly soluble in an excess, when much carbonate of soda is present. FeS is easily soluble in HCl, being converted into $FeCl_2$ with evolution of H_2S.

Ferrocyanide of potassium gives with ferrous salts a white precipitate, or with solutions containing small quantities of ferric salts, a bluish-white one, $FeCy_2 + KCy$, which, on exposure to the air, changes quickly into Prussian blue.

Ferricyanide of potassium gives at once a fine blue precipitate (Turnbull's blue), $3FeCy_2 + FeCy_6$, a characteristic distinction of the two oxides.

Tincture of galls produces no change, unless the ferrous salts contain some sesquioxide, except in very concentrated solution, when a white gelatinous precipitate forms, which rapidly oxidizes to blue-black.

* Except the *ferrous acetate*, which is partially precipitated, even in the presence of *free acetic acid*.

Ferrous salts reduce chloride of gold and nitrate of silver to the metallic condition.

Ferric oxide (sesquioxide of iron), Fe_2O_3. This reddish-brown powder remains unchanged when ignited by itself in O. F. In this form iron is always determined quantitatively. Fe_2O_3 is completely soluble in HCl; the native oxide, or that which has been previously ignited, is only slowly soluble. Ferric salts in dilute, and as nearly as possible neutral, solution or when the solution is previously treated with acetate of sodium, are decomposed at a boiling heat, basic salts being precipitated; if phosphoric or arsenic acid be present these acids will be contained in the precipitate. By warming an acid solution of ferric salts with metallic iron, zinc, or with sulphurous acid, or by passing H_2S through it, they are reduced to ferrous salts. On the contrary, solutions of ferrous salts are converted into ferric salts if, at a boiling heat, some nitric acid is added. The presence of another free acid (*e. g.*, HCl or H_2SO_4) is advantageous. The nitric acid is thereby decomposed, and nitric oxide gas, (NO, turning in part to red NO_2 fumes in the air) is given off. Chlorine gas likewise causes an analogous oxidation of ferrous salts. Thus, if one of the latter, after being acidulated with HCl, is warmed and some chlorate of potassium, $KClO_3$, is added (not more than 2 or 3 crystals), the HCl is decomposed into water and chlorine, which latter, indicated by its odor, accomplishes the oxidation thus:

$$2FeCl_2 + Cl_2 = (Fe_2)Cl_6.$$

The following equation expresses the action of chlorate of potassium:—

$$6FeCl_2 + 6HCl + KClO_3 = 3Fe_2Cl_6 + 3H_2O + KCl.$$

Free chlorine gas, or chlorine water, may be thus employed, or chlorides, such as the perchloride of tin, $SnCl_4$, which yield chlorine. In the separation of Fe_2O_3 from FeO, MnO, etc., we precipitate the Fe_2O_3 with carbonate of barium, which precipitates the Fe_2O_3 completely, even in the cold, while ferrous oxide remains unaltered in the solution, if access of air is excluded.

The two oxides, when both are present at the same time, are found by two experiments: 1st, with ferricyanide of potassium (red prussiate of potash) we test for *ferrous* oxide (blue precipitate); and 2d, with ferrocyanide of potassium (yellow prussiate of potash) we test for *ferric* oxide (blue precipitate). From the alkalies sesquioxide of iron is separated by ammonia; from the alkaline earths and magnesia, by precipitating with ammonia, in the presence of sal ammoniac, and boiling until the odor of ammonia disappears. Oxides of the formula MO, that were likewise partially thrown down, thus pass again into solution. From manganese, nickel and cobalt, it is more readily separated if the dilute solution, containing ferric oxide, is neutralized with carbonate of sodium until it turns brownish-red, then acetate of sodium added and heated to boiling, when only the iron (as basic ferric acetate) is thrown down.

Tincture of galls precipitates ferric salts bluish-black (ink).

Sulphocyanide of potassium (KCNS) produces a blood-red color, which is not destroyed by HCl, but disappears in the presence of acetate of sodium.

Ferric acid, FeO_3, is only known in combination with

alkalies, forming fine, amethystine-red solutions, *e. g.*, potassium ferrate, K_2FeO_4.

LANTHANUM.—This rare element occurs with cerium in a number of minerals. Its oxide is white and remains white upon ignition in the air (distinction from cerium). Its salts react with potassium sulphate, oxalic acid, and barium carbonate like the salts of cerium. Caustic potash precipitates the hydrate, insoluble in excess, and not turning yellow in the air (this last a distinction from cerium). The precipitate with ammonia is hard to filter. The precipitate with ammonium carbonate is insoluble in excess (distinction from cerium). A cold dilute solution of lanthanum acetate supersaturated with ammonia, the shiny precipitate washed and a little iodine in powder added, gradually assumes a blue color (distinctive test).

LEAD.—B. B. with soda on charcoal, a malleable globule of metallic lead is obtained from lead compounds; the coating has a yellow color (oxide) near the assay (red when hot), and further off a white color (carbonate); on being touched with the R. F. both of these disappear, tinging the flame azure-blue. Heated with S + KI mixture, lead compounds give a yellow to parrot-green coating of lead iodide on the charcoal. In solutions, dilute sulphuric acid gives a white precipitate of lead sulphate, nearly insoluble in water and in dilute acids. The acid mixture is then best evaporated on a water-bath, and water added to the residue, when the lead sulphate, if present, may be further experimented with. This precipitate, $PbSO_4$, is soluble in caustic potassa, also in tartrate of ammonium, containing an excess of ammonia, from which latter solution it can be precipi-

:ated by *sulphide of ammonium* (*black*) or *chromate of* ɔotassium (*yellow*); by being boiled with carbonate of ɜodium, $PbSO_4$ is completely converted into carbonate ɔf lead. Salts of lead are precipitated both by sulphide of hydrogen and sulphide of ammonium, the black precipitate, PbS, being insoluble in dilute acids, potassa, and sulphide of ammonium. In the presence of much free HCl, the precipitated sulphide of lead looks brown or almost red. When in thick masses, such as the common sheets and pipes of commerce, lead is scarcely at all acted upon by cold sulphuric acid, and is but slowly corroded by hydrochloric acid. Both these acids form, by their action on the lead, nearly insoluble salts, and as soon as a layer of the salt has once been deposited upon the surface of the metal, the latter is thereby protected from further corrosion. On exposure to the air lead soon tarnishes, owing to the formation of a thin coating of *lead suboxide*. By the simultaneous or alternate action of water and air, lead is very rapidly corroded in consequence of the formation of a *lead hydrate*, which is converted by the carbonic acid in the air into lead carbonate. All natural waters act more or less on lead. In some cases the action is so slight that lead pipes are used with safety for conveying the water; in other cases, the use of lead pipes is very dangerous on account of the poisonous character of the salts of lead. The author of this book has had frequent occasion to test the water, which passed through lead pipes, for this injurious ingredient. Even very minute quantities of lead may be traced thus: A measured quantity of suspected water is evaporated nearly to dryness, and the thus concentrated liquid placed in a small, bright,

new porcelain dish, where it is first acidulated with pure acetic acid, and next sulphide of hydrogen passed into it, when, if lead is present, either a black or brown precipitate of PbS is thrown down. Owing to the presence of free acetic acid, ordinary metals like iron do not interfere with the reaction.

LITHIUM.—Lithia is found in small quantities in petalite, spodumene, amblygonite, lepidolite, triphylite, etc., and also in the waters of mineral springs.

B. B. salts of lithium impart a carmine color to the gas flame or blowpipe flame, the recognition of which is not prevented by the presence of potassa, but is interfered with by the intensely yellow color of the salts of sodium. Silicates containing but little lithium scarcely tinge the flame, but if the fine mineral powder is mixed with one part of finely pulverized fluor-spar, and one and a half parts of bisulphate of potassium, the whole kneaded with some water into a paste, and this exposed on platinum wire to the point of the blue cone of the flame, the outer flame will be colored distinctly red; if no lithium be present, the mixture gives a faint violet flame. Chapman has shown that the lithium flame, unlike strontium, is not obscured by the presence of barium. He suggests fusing lithium minerals with chloride of barium. Thus, if triphylite (an iron-manganese-lithium phosphate) is treated in this manner, it yields a beautiful crimson color. (See *flame reactions.*)

The salts of *lithium* are all soluble in water, but the oxide, carbonate, and phosphate of lithium are nearly *insoluble* in water; hence salts of lithium, in concentrated solution, will give precipitates with carbonate or phosphate of sodium, especially when they are heated and

somewhat evaporated. Lithium-platinic chloride is soluble in water, alcohol, and ether.

MAGNESIUM, B. B.—Magnesia, and many magnesian silicates, afford a clear rose-red color on intense ignition with cobalt solution. A fragment after heating should be moistened with the solution and then heated again; the color deepens on cooling. Magnesium is distinguished from barium and strontium in the wet way, by the fact that sulphuric acid gives no precipitate in dilute or concentrated HCl solutions of magnesium salts, but gives a precipitate in concentrated solutions of calcium salts, and in dilute solutions of barium and strontium salts. The calcium sulphate differs from barium and strontium sulphates by being soluble in a *concentrated solution of ammonium sulphate.*

The metals of the alkaline earths, like those of the alkalies, occur only in the form of *salts.* Their oxides, the alkaline earths (BaO, SrO, CaO), are soluble in water, taking up first a portion thereof and forming, with evolution of heat, *hydrates* of the general formula $M(OH)_2$. *Magnesia*, MgO, is insoluble in water, though with difficulty soluble as freshly precipitated *hydrate.* The alkaline earth carbonates, MCO_3, and phosphates, $M_3(PO_4)_2$, are insoluble in water but soluble in acids; the soluble salts of the alkaline earths are hence precipitated by *soluble* and *neutral* carbonate and phosphate salts.

Owing to the possibility that the carbonates of Ba, Sr, and Ca may be partly retained in solution by the free carbonic acid, the precipitation with carbonate of ammonium should take place with the liquid slightly warmed and in the presence of *free* ammonia. The pre-

cipitation is somewhat slow, but complete in the absence of other *ammonium salts*, especially of *chloride of ammonium*.

For qualitative analysis the following reactions are not without some importance. The phosphates of the alkaline earths, viz., $Ba_3(PO_4)_2$, $Sr_3(PO_4)_2$, $Ca_3(PO_4)_2$, are obtained by precipitating with a *soluble phosphate*. The precipitates are white, amorphous, soluble in mineral and acetic acids, but insoluble in water. Consult *Magnesium*, p. 169.

Solubility of the *chlorides* and *nitrates* of the alkaline earths in alcohol—

$BaCl_2$ $Ba(NO_3)_2$	} insoluble.	$SrCl_2$ $Sr(NO_3)_2$	} soluble insoluble.	$CaCl_2$ $Ca(NO_3)_2$	} soluble.

These reactions can be used for the separation of the group mentioned (also quantitative) in the absence of water, *i. e.*, the salt must be completely dry, and the alcohol must be anhydrous (100 p. c.).

Deportment of the Alkaline Carbonates with the Alkaline Earths.

When the *sulphates of barium, strontium*, and *calcium* are fused in a crucible with carbonate of potassium or sodium, they are quickly and completely converted into carbonates. By merely boiling with a concentrated solution of carbonate of sodium, the sulphates of strontium and of calcium pass readily into carbonates, whilst the sulphate of barium decomposes very slowly, and the solution of the carbonate of sodium must be repeatedly poured off, and replaced by a new portion, and heat applied.

Separation of Sulphate of Strontium from *Sulphate of Calcium* by *Sulphate of Ammonium.*

A solution of *sulphate of ammonium* in large excess (1 part of dry salt and 4 parts of water) after boiling for one hour, or in contact for twelve hours at the ordinary temperature, dissolves *sulphate of calcium* completely, whilst *sulphate of strontium* (and sulphate of barium) are not altered. From the solution of the sulphate of ammonium the lime is precipitated as *oxalate of calcium*, which, on ignition, forms carbonate of calcium.

Sulphuric acid and soluble sulphates produce no precipitate in a solution of a magnesium salt, but the fixed caustic alkalies, and also baryta, and lime-water, especially at a slightly elevated temperature, throw down all the magnesium in form of a hydrate, $Mg(OH)_2$, which, however, upon addition of an ammonium salt, in sufficient quantity, disappears again, or when ammonium salts are present, is not precipitated at all.* The fixed carbonates of the alkalies throw down at a boiling heat all the magnesia in the form of gelatinous basic carbonate of magnesium (*magnesia alba*), $3MgCO_3 + Mg(OH)_2 + 4H_2O$, but only in the absence of ammonium salts.

Phosphate of sodium (HNa_2PO_4), produces, even in dilute solutions of magnesium salts, in the presence of sal-ammoniac and free ammonia, a white crystalline precipitate, $Mg(NH_4)PO_4$, soluble in acids, even acetic acid, but entirely insoluble in dilute ammonia, with which it is washed when filtered. When ignited it passes into *pyrophosphate of magnesium*, $Mg_2P_2O_7$.

* For 1 mol. of magnesium salt at least 4 mol. of carbonate of ammonium are required.

MANGANESE.—The oxide (Mn_2O_3) gives with borax in the O. F. an amethystine bead (very dark with excess), which becomes colorless in the R. F. (protoxide). With salt of phosphorus the bead requires more saturation than with borax, otherwise the reaction is similar. The soda test when executed on platinum foil, or in the loop of platinum wire, is the most characteristic test in case of admixture with other coloring oxides. The deep green color of the opaque soda bead is more quickly obtained when a small fragment of nitre, or of chlorate of potassium is added to the assay before fusion. When testing substances which do not dissolve readily in soda, it is well to add a little borax to the bead, and this also makes the test much more delicate (Chapman). By this operation the manganese is oxidized to manganic acid, which forms with soda, green *manganate of sodium*, Na_2MnO_4.

Manganese forms with oxygen a series of compounds, viz., *Manganous oxide*, MnO, *Manganic oxide*, (sesquioxide), Mn_2O_3, *Manganese dioxide* (pyrolusite), MnO_2, *Manganic anhydride*, MnO_3, forming manganates, but not known as an acid. *Permanganic anhydride*, Mn_2O_7, only used as *permanganate*, is a powerful oxidizing agent. The *manganous salts* are either of a rose color or colorless, mostly soluble in water, the solution undergoing no higher oxidation in the air; the sulphate is permanent, even when ignited. All the oxides (and carbonates) of manganese form, when ignited, *manganous-manganic oxide* (Mn_3O_4). All the higher oxides, on being heated with HCl, pass into the condition of manganous chloride ($MnCl_2$), corresponding with manganous oxide (MnO), *e. g.*,

$$MnO_2 + 4HCl = MnCl_2 + 2Cl + 2H_2O.$$

anganic oxide is not decomposed by HCl in the cold. ted with concentrated sulphuric acid all the higher les evolve oxygen with formation of $MnSO_4$.

ydrogen sulphide produces no precipitate in solutions *anganous salts*, except a slight precipitate with the ate.

ulphide of ammonium gives a flesh colored precipitate *anganous sulphide*, MnS. Acetic acid acting on precipitated sulphides, dissolves the MnS and sepa- s manganese from cobalt and nickel, and from a part inc (separation of zinc from manganese and other als).

e may also proceed thus: To the solution to be ex- ned we add acetate of sodium, and precipitate with , which throws down sulphide of zinc, and leaves olution manganese and iron. Acid solutions must viously be neutralized with carbonate of sodium il they become slightly turbid, and next be acidu- d with *acetic acid*.

InS when dissolved in acetic acid in the air gives off , takes up oxygen, and turns *brownish-black*.

austic potash or soda precipitates white manganous lrate, $Mn(OH)_2$, insoluble in excess, and becoming ckly brown in the air, and it is then no longer *com- ely* soluble in *chloride of ammonium*.

mmonia gives in acid solutions of the manganous s, or in those which contain ammoniacal salts, no cipitate at first, but the solution becomes turbid on osure to the air, and (if sufficient ammonia be used) osits all the metal as brown hydroxide of manga- e, MnO.OH.

lkaline carbonates, phosphates, arseniates, and *lates produce white* precipitates.

Ferrocyanide of potassium gives a white precipitate with manganese salts, and ferricyanide of potassium a brownish-yellow one. If lead dioxide or superoxide $(PbO)_2$, or minium $(2PbO, PbO_2)$ be heated with an excess of nitric acid, and a trace of a manganous salt be added (or the solution to be tested for manganese free from sal-ammoniac), the fluid assumes the intense *purple color* of *permanganic acid*, which is very perceptible after the separation of the excess of dioxide of lead (a delicate test for manganese).

Manganic oxide (sesquioxide), Mn_2O_3, as well as the corresponding hydroxide, MnO.OH, form brownish-black powders. The solution in cold sulphuric acid is cherry-red or crimson, and passes, like other manganic salts, into *manganous salts*, with a loss of color when in contact with reducing agents (hydrochloric, sulphurous, and nitrous acids, organic matters, etc.), or when heated by themselves. Dioxide of manganese (peroxide), MnO_2, is the most important native mineral (pyrolusite).

By ignition it yields one-third part of oxygen gas, and when treated with concentrated sulphuric acid half its contents of oxygen.

Permanganic acid.—Its salts dissolve in water with an intense purple color, which is immediately decolorized by organic materials (analysis of water), and by most reducing agents.

Mercury and Amalgams yield a sublimate of finely divided metallic mercury, when heated in the closed tube. Compounds of mercury heated in the closed tube together with soda, yield also metallic mercury which condenses above the assay. When a gray sublimate is

obtained, without exhibiting distinct metallic globules, these may be made to coalesce by means of a feather; or the part of the tube containing the sublimate is cut off with a file, brought into a test-tube, and boiled with some dilute HCl, by which treatment the mercury unites in shining globules. In cases where mercury is present in such small quantities that no distinct sublimate is formed, it may be detected by inserting into the tube a piece of gold-leaf wrapped around the end of an iron wire and held just above the assay. On heating, the mercury is volatilized, and combining with the gold forms a grayish-white amalgam.

Mercurous compounds of ordinary occurrence are insoluble in water, except the normal nitrate, the sulphate, and the acetate, which are sparingly soluble (300 to 600 parts of water). All these require acidulated water for their solution, becoming decomposed by *water* at a certain degree of dilution, with precipitation of *basic salts.*

Solutions of *mercurous salts* are precipitated by HCl and by soluble chlorides, the precipitate being white *mercurous chloride* or *calomel*, Hg_2Cl_2, which turns black with caustic potash or ammonia.

Solutions of *mercuric oxide*, HgO, are not precipitated by HCl, since the *mercuric chloride* (corrosive sublimate) is soluble in about twelve parts of cold, or two to three parts of boiling water, and freely soluble in alcohol and ether.

Stannous chloride ($SnCl_2$) throws down calomel from mercuric chloride ($HgCl_2$) solutions. A clean strip of copper, placed in a slightly acid solution of a salt of mercury, becomes coated with *metallic mercury*, and

when gently rubbed with cloth or paper presents the tin-white luster of the metal; this coating is driven off by heat.

MOLYBDENUM.—B. B., on charcoal, gives, near the point of heating, a copper-red stain in the O. F. on cooling, which becomes azure-blue when touched for a moment with the R. F. Beyond this inner coating a white or faint yellowish coating of MoO_3 is formed. The oxide imparts no color to the borax bead in O. F., but on reduction the saturated bead becomes a black enamel; the less saturated bead smoky on cooling. In the salt of phosphorus bead the color is in O. F., pale yellow-green when hot, paler when cold, and in R. F. dirty green when hot, clear green when cold.

When molybdenum is present in small quantities, particularly when associated with copper or tin, as in some furnace products, it is necessary to have recourse to the wet way. The silver-white molybdenum is not oxidized in the air at any ordinary temperature, but when slowly heated it assumes a brownish-yellow, then a blue, tarnish, and at a higher temperature it burns off to MoO_3. It is speedily oxidized by nitric acid to molybdic anhydride (MoO_3), with evolution of nitrous fumes; slowly by hot sulphuric acid, with evolution of SO_2. Molybdenum forms three classes of compounds, viz., *molybdous oxide*, MoO, chloride, $MoCl_2$, and other molybdous salts; *molybdic oxide*, MoO_2, chloride, $MoCl_4$, and corresponding salts; and *molybdic anhydride*, MoO_3, with the corresponding molybdates. From *molybdous salts*, as $Mo(NO_3)_2$, alkaline hydrates or carbonates precipitate dark brown *molybdous hydrate*, becoming blue in the air by oxidation to *molybdic-molybdate*, $Mo(MoO_4)_2$ and

Mo_2O_5. *Molybdic anhydride*, MoO_3, is white, lemon-yellow when heated, fuses at a red heat, and sublimes. Hydrochloric acid separates from alkaline molybdates, *e. g.*, K_2MoO_4, white crystalline molybdic acid, soluble again in an excess of the acid. This latter acid solution, or the HCl solution, assumes, in contact with zinc, at first a blue, then a green, and finally a brown, color. The addition of sulphocyanide of potassium changes the brown solution to red. The same red tint is obtained when the hydrochloric acid solution of a molybdate is treated with sulphocyanide of potassium. Ether withdraws this color from the liquid, assuming an orange tint, which, on exposure to the air, turns to crimson (the most delicate reaction for molybdenum). H_2S in acid solutions of molybdic acid gradually produces a brown precipitate, MoS_2, soluble in $(NH_4)_2S$, forming $(NH_4)_2MoS_4$, while the supernatant liquid appears blue or green. The same precipitate is formed when the aqueous solution of an alkaline molybdate, after being saturated with H_2S, or after the addition of $(NH_4)_2S$, is acidulated with HCl. When the powdered compound of molybdic acid is heated, on platinum foil, with a drop of strong sulphuric acid and a little organic matter, as a minute fragment of paper, a blue color is obtained; or it is still better to heat the pulverized substance in a small porcelain dish with a little concentrated sulphuric acid, and then add alcohol, when the liquid assumes a sky-blue color if molybdic acid is present. For the reaction of molybdate of ammonium with phosphoric acid see "Phosphates," page 182.

NICKEL, B. B.—Oxide of nickel gives, with salt of phosphorus, in the O. F. a reddish-brown bead when

hot, and pale-yellow on cooling. With larger quantities of oxide these colors are darker. In the R. F. the colors remain unchanged or become somewhat paler, but with tin on charcoal the bead may be decolorized. In the borax bead in O. F. nickel is violet to purple when hot, becoming reddish-brown on cooling. When heated in the strong reducing flame the bead becomes brown to opaque, but on continued heating it becomes colorless with separation of particles of gray metallic nickel. Upon charcoal in the R. F., especially upon addition of granulated tin, the reduction is quickened and the reduced nickel unites with the tin to a metallic globule.

All the salts of the protoxide, or nickelous oxide, NiO, are *yellow* when anhydrous; as hydrates, or in solution, *green;* they redden litmus paper, and are decomposed on ignition. The neutral salts (containing *no free* acid) are only partially decomposed by H_2S; and, when acidulated with HCl, not at all; nickel acetate or any nickel salt, previously treated with acetate of sodium, is completely precipitated by H_2S when the solution is warmed, and contains not too much free *acetic acid.* The precipitated black sulphide of nickel (NiS) is with difficulty soluble in dilute hydrochloric, and in acetic acids, though very soluble in nitric, and nitro-hydrochloric acids. $(NH_4)_2S$, likewise throws down from a neutral solution sulphide of nickel, of which only a very small quantity remains soluble in excess, giving it a brown color. On this account a brown color of the liquid which is poured off from the precipitate produced by $(NH_4)_2S$ indicates *nickel.*

Potassium hydrate throws down apple-green *nickel hydroxide* $= Ni(OH)_2$, insoluble in excess, soluble in

ammonia salts. Acid solutions of nickel salts, or those containing sal-ammoniac, are not precipitated by ammonia; neutral solutions only partially; the precipitate is soluble in an excess of ammonia with a pale sky-blue color. Caustic potash throws down gradually from this solution $Ni(OH)_2$. Carbonates of the alkalies precipitate basic carbonates; the precipitate being soluble in an excess of the precipitant.

Nitrite of potassium produces in very concentrated nickel solutions only a brownish-red precipitate of potassio-nickelous nitrite $= Ni(NO_2)_2 + 4KNO_2$, soluble upon addition of water. In the presence of carbonates of the alkaline earths (Ba, Sr, Ca), said reagent throws down, even in dilute nickel solutions, nearly all the metal in the form of yellow crystalline salt, $NiMK_2(NO_2)_6$, (M = Ba, Sr, or Ca), which in cold water is with great difficulty, in boiling water easily, soluble, with a green color, decomposition taking place.

Ferrocyanide of potassium yields a greenish-white, ferricyanide of potassium a yellowish-green, precipitate.

Cyanide of potassium precipitates nickelous cyanide, soluble in excess; the solution contains potassio-nickelous cyanide $= K_2Ni(CN)_4$ from which dilute HCl, or H_2SO_4, again throws down $Ni(CN)_2$, with evolution of hydrocyanic acid.

If the solution of $K_2Ni(CN)_4$, is treated with an alkaline solution of hypochlorite of sodium, and heat applied, blackish-brown nickelic hydrate, $Ni(OH)_3$, is thrown down. The same happens when the nickelous hydrate, diffused in water (or better in dilute alkali) or a solution of cyanide of nickel, is treated with chlorine. Free acids, even acetic acid, prevent its formation. On

this reaction rests a method of *separating nickel from cobalt.*

NIOBIUM, Nb.—Marignac has shown that nearly all tantalites and columbites contain both tantalum and niobium. To obtain free niobic acid, Nb_2O_5, and tantalic acid, Ta_2O_5, the powdered minerals are fused with six parts of bisulphate of potassium until completely dissolved. The fused mass is treated with hot water, when both acids remain behind, while the bases and titanic acid, if present, will be dissolved, and can thus be separated. The residue is washed with ammonia and sulphide of ammonium to remove tungstic acid and oxide of tin, while hydrochloric acid dissolves any iron. The filtered and thoroughly washed residue is now treated with either HCl or H_2SO_4 in a porcelain dish, and metallic zinc added. If a tantalate alone be present, no coloration or but a slight one ensues; a columbate thus treated assumes a blue color, which gradually fades, and finally turns brown.

NITRIC ACID (AND NITRATES).—When nitrates are fused in a glass tube with bisulphate of potassium, reddish-brown fumes are evolved (NO_2 and NO), which become readily visible when the tube is held against a white back-ground or examined lengthwise. All nitrates deflagrate when heated on charcoal; those of the alkalies and alkaline earths (calcium nitrate) deflagrate with violence, and are converted into carbonates.

OSMIUM.—Osmium generally occurs in platinum ores, as iridosmine, a native alloy of iridium and osmium. Heated in the open tube the volatile oxide, OsO_4, is formed, having a characteristic pungent odor, and pro-

ducing a luminous flame when the vapor is allowed to escape from the tube into a Bunsen flame.

OXYGEN.—All combustible substances burn in oxygen gas with great brilliancy, hence if this element is given off from some compound heated in a closed tube, and an ignited splinter of charcoal be brought into the gas, it will burn with greatly increased brilliancy.

PALLADIUM.—Oxide of palladium, PdO, is reduced on ignition B. B., but the metallic particles cannot be fused together. With borax on platinum wire in O. F. it is reduced without dissolving in the flux. The metallic particles cannot be united together to a globule even on charcoal in R. F., as in O. F. With salt of phosphorus it gives the same reaction. With soda on charcoal insoluble; the soda is absorbed by the charcoal, leaving the Pd behind as an infusible powder.

Palladium occurs in a tolerably pure state with Brazilian platinum ore; also alloyed with gold. It is darker than platinum; heated in the air, it oxidizes and turns blue; at a higher temperature the oxide is again destroyed. In the alcohol flame the metal becomes covered with soot; it is capable of condensing enormous quantities of hydrogen gas. In nitric acid it is with difficulty dissolved. In hot hydrochloric and sulphuric acids, scarcely soluble; in aqua regia, readily soluble. With oxygen it forms three oxides, Pd_2O, PdO and PdO_2. PdO is the common compound. $PdCl_4$ is produced with aqua regia, and combines with other chlorides, *e. g.*, K_2PdCl_6. Palladic chloride loses chlorine easily, passing into palladious chloride, $PdCl_2$, and to this correspond the other palladious salts. Iron vitriol reduces palladium salts slowly to metallic palladium

(black). Stannous chloride produces a black precipitate, and gives a green solution. Iodide of potassium produces, even in dilute solutions, a black precipitate of palladious iodide, PdI_2, quite insoluble in water, and suitable for the quantitative determination of iodine.

PHOSPHORIC ACID OR PHOSPHATES.—The green color (see flame reactions, p. 102) which phosphates impart B. B. to the flame, especially upon the addition of a drop of concentrated sulphuric acid, serves often for their detection.

If a previously pulverized and well-dried phosphate is mixed with soda and heated to a red heat in a closed tube with a piece of magnesium-wire or metallic sodium, the phosphoric acid will be reduced to phosphide. If the tube is then broken, and the piece containing the fused assay is, after cooling, moistened with a little water, phosphoretted hydrogen, PH_3, is given off, having the characteristic disagreeable odor of decaying fish.

If a phosphate is dissolved B. B. in a borax bead to which some carbonate of sodium has been added, and tungstate of sodium is introduced, the bead upon being heated in the R. F. turns blue, while tungstic acid alone colors a borax bead in the R. F. yellowish-brown.

In the wet way it is traced, even in very minute quantities, thus: A few drops of a neutral or acid solution containing phosphoric acid are poured into a test-tube which is then filled to the depth of an inch with a solution of *molybdate of ammonium* containing much *free nitric acid;* there is formed a pale yellow precipitate termed *ammonium phosphomolybdate.* For the full delicacy of the test, especially if mere traces of phosphoric acid are present, the mixture should be set aside for

several hours at a temperature of 30° to 40° C. or heated to 80° C. and agitated for a few minutes.

Silicic acid, with which phosphoric acid might be confounded, produces a strongly yellow coloration, but does not yield a precipitate, whilst arsenic compounds in solution furnish a yellow precipitate of ammonium arsenio-molybdate looking like the phosphomolybdate.

PLATINUM.—Platinum occurs native, alloyed with other metals, as iron; also as arsenide. It is generally separated from the sands in which it occurs by washing or panning, and may then be subjected to tests. The metal is insoluble in HCl, HFl, H_2SO_4, and HNO_3, but soluble in *aqua regia* to platinic chloride, $PtCl_4$. From this reddish-yellow solution H_2S throws down dark-brown platinum sulphide PtS_2, soluble in an excess of yellow ammonium sulphide. Stannous chloride colors the solution of platinum dark brownish-red. For the reactions of $PtCl_4$ with KCl and NH_4Cl, consult potassium (below) and ammonium, page 128.

POTASSIUM.—For flame reactions, see p. 103. A glass of borax containing potassa becomes blue when a little oxide of nickel * is carefully added, with soda alone a brown bead is obtained on cooling.

For the detection of potassium in compounds in the wet way, platinic chloride ($PtCl_4$) is added to neutral and acid solutions of the compound substance (not too dilute), together with HCl (if the compound be not a chloride), when a yellow crystalline precipitate of potas-

* Oxalate or carbonate of nickel may also be employed. It must be free from cobalt (must not furnish a blue glass with borax). Admixtures of soda and lithia do not interfere with the reaction if the potassa is present in sufficient quantity.

sium platinic chloride $(KCl)_2PtCl_4$ is thrown down. Since ammonium salts are also precipitated by this reagent, with closely resembling color and form, these, if present, must be first removed (volatilized). Minute portions of potassium are detected by evaporating the solution with the reagent nearly to dryness on the water-bath, and then dissolving the mass in alcohol; the yellow crystalline precipitate *octahedral*, remains undissolved, and may be identified under the microscope.

RHODIUM.—Rhodium is contained in platinum ores (0.4 to 1.0 p. c.). It is soluble in *aqua regia* only when in an alloyed condition (with Pt or Cu). It is soluble on fusion with bisulphate of potassium or metaphosphoric acid. From the warm solution obtained from the fusion, H_2S precipitates slowly, Rh_2S_3; insoluble in $(NH_4)_2S$. When the solution is treated with some caustic potassa solution, and a few drops of alcohol added, a black precipitate of rhodium hydrate, $Rh(OH)_3$, falls, at ordinary temperature.

RUBIDIUM.—The oxide, rubidia, a very rare alkali, gives B. B. a violet flame, and when mixed with cæsia and potassa can only be distinguished by spectroscopic examination.

RUTHENIUM is alloyed with platinum, and found as laurite, RuS_2, in the platinum ore of Borneo. Insoluble in acids. By fusion with caustic potassa and chlorate of potassium or saltpetre, an orange-colored K_2RuO_4 is formed, from the solution of which nitric acid separates black sesquioxide. Chlorine throws down anhydrous RuO_4. From the orange solution of the *sesquioxide in* HCl, hydrogen sulphide (which colors it *at first blue*) throws down, after a while, brown sulphide.

Sulphocyanide of potassium (in the absence of other platinum metals) causes a purple-red, and, when heated, a violet coloration.

SELENIUM and SELENIDES yield in the closed tube at a high temperature, a sublimate which is reddish or black, producing a red powder; and give off at the same time the odor of decaying horse-radish. In the open tube they evolve the same characteristic odor, and yield a sublimate of selenium mixed with oxide; which near the assay is steel gray, and further off red.

Selenites and selenates are reduced to selenides B. B. on charcoal in R. F. with the characteristic odor of selenium.

Selenium is steel-gray to reddish-brown with a faint metallic luster; it fuses very easily; volatilizes with yellowish-brown fumes, giving the odor of decaying horse-radish; is usually soluble in bisulphide of carbon, and imparts B. B. a blue color to the O. F.

SILICON, or the oxide, SILICA, SiO_2, when heated with soda gives a clear glass, if the soda be not in excess. The oxide, SiO_2, causes a strong effervescence when introduced into the soda bead. This reaction distinguishes silica from the earths; silicates may, however, contain alumina, and still fuse with soda to a clear glass.

In most silicates the silica may be detected by the help of salt of phosphorus. Most silicates, when added to a bead of that salt and heated, are decomposed; the bases dissolve in the free phosphoric acid without interfering with its transparency (unless the substance is present in too large a quantity), while the silica, being almost insoluble, floats as a translucent spongy mass

in the bead. The latter must be carefully observed while hot, since many silicates form a glass which, on cooling, becomes opalescent or turbid. This is not a delicate or sure test, but is simple, and convenient in many cases.

When a finely-powdered silicate is fused with an excess of carbonate of sodium, the resulting mass dissolved in dilute HCl, and evaporated to dryness, the silica is rendered insoluble; and on moistening the residue with strong HCl, and dissolving it in hot water, all the silica will remain behind; and can be separated from the bases by filtration and washing.

Most of the hydrous silicates and many which are anhydrous, but which contain an excess of base, as orthosilicates, are decomposed by strong HCl, the bases uniting with the HCl, while the silica separates, either as a *gelatinous hydrate* or as a *non-gelatinous powder*.

SILVER.—This metal is easily recognized by its physical characters, as also by the brown coating it gives when strongly heated in O. F. on charcoal. When combined with easily oxidizable metals, it may be separated by heating on charcoal in O. F. If silver be associated with a large quantity of lead or bismuth, it is best to subject it to cupellation. The following process serves for its complete separation from most argentiferous ores. The finely powdered substance is mixed with an equal bulk of borax glass and a like bulk of pure granulated lead (except in cases where lead or its oxide already exists, as in litharge, minium, cerussite). The mixture, wrapped in paper soaked in Na_2CO_3, is placed in a cylindrical cavity in the charcoal, and fused in R. F. until the earthly matters have been dissolved and the metallic

particles united into one globule; the latter is subjected for a short time to the O. F. (until, on cooling, the surface of the lead bead is red or yellow), thereby separating volatile and easily oxidizable substances that may be present. The remaining globule, containing a large excess of lead and all the silver, is then mechanically separated from the flux, and subjected to cupellation.

For this purpose finely pulverized bone-ash is placed in a circular cavity in charcoal, half an inch in diameter and one-quarter inch deep, and the surface of it made concave and smooth by pressing it with an agate pestle or any other suitable convex surface. This *cupel* is now carefully exposed to a gentle heat till perfectly dry. The lead globule, freed from adhering flux, is then placed upon the cupel and exposed to O. F. Should much nickel and copper be present, an infusible coating is formed which prevents the desired oxidation; this may be counteracted by the addition of a small quantity of lead. The blast is kept up until all traces of lead have become oxidized. This is indicated by the cessation of the rainbow colors of the oxide of lead which play over the surface of the globule. When the quantity of litharge that is formed in the process of cupellation is large, the globule of silver, still containing lead, may be removed to a fresh cupel, and there finally refined. The instant when the last traces of lead disappear is then readily perceived by the sudden brightening of the globule. The remaining metal, when free from gold, has a silver-white color. It may be tested for gold as described under that metal.

In the wet way silver is determined, in almost all cases, as chloride of silver, AgCl, and separated from

other metals; its insolubility in acids and solubility in ammonia distinguish it readily from all the other chlorides that are insoluble, or with difficulty soluble. Some metals, such as zinc, iron and copper, ferrous sulphate (or, perhaps better, ferrous acetate), stannous chloride, sulphurous acid, and many *organic compounds*, precipitate metallic silver from its solutions.

Sodium.—It is readily distinguished, even in compound substances, by the intense yellow color it imparts to the outer blowpipe flame. The sodium flame is invisible when observed through cobalt-blue glass and red glass; with green glass it is orange-colored (sensitive reaction). Sodium is not precipitated by platinic chloride, since it forms a compound soluble in water, alcohol and ether.

Compare flame reactions, p. 103.

Strontium.—Strontium compounds color the flame *scarlet*. In the presence of barium the scarlet color appears at the moment when the substance, moistened with HCl, is first brought into the flame. The paler, yellowish-red flame of calcium is liable to be mistaken for the strontium flame. Consult flame-colors, pp. 105 and 106.

In *solubility*, most compounds of strontium closely resemble those of barium, the hydrate being a little less soluble, and the sulphate and chromate more soluble in water than the corresponding barium compounds, and the silico-fluoride quite soluble. The chloride is soluble, the nitrate insoluble, in absolute alcohol (100 per cent.).

Strontium sulphate ($SrSO_4$), like barium sulphate, is almost insoluble in concentrated solution of ammonium

sulphate, white sulphate of calcium is soluble, and may thus be separated. A saturated solution of calcium sulphate ($CaSO_4$) slowly produces a faint precipitate of $SrSO_4$, prevented, or dissolved, by the presence of HCl and HNO_3, but quite insoluble in alcohol. An aqueous solution of calcium sulphate (gypsum) may, therefore, be the simple means of distinguishing calcium, barium and strontium salts, when soluble in water. No precipitate will be formed if lime is present, while a *baryta* solution will at once be rendered turbid, or afford a precipitate, and *strontia* gives a faint precipitate only after some time. An addition of alcohol, however, completely precipitates sulphate of strontium and sulphate of calcium.

SULPHUR.—Free sulphur fuses and forms a yellow sublimate in the closed tube. In an open tube, or on charcoal, it burns, yielding sulphurous anhydride, SO_2. The higher sulphides give off sulphur in the closed tube; the neutral sulphides and subsulphides give off sulphurous anhydride when heated in the open tube, recognizable by its odor and the reddening and finally bleaching of moistened blue litmus paper.

In the investigation B. B. of sulphur compounds, a lamp or candle-flame should be employed, since ordinary coal gas often contains considerable quantities of sulphur. The sulphur in sulphides and sulphates may be detected B. B. by fusing small quantities on charcoal with two or three parts of soda in the R. F. The sulphur is thereby converted into sulphide of sodium, which, when placed on clean silver-foil, or on a bright silver coin, and moistened with a drop of water, blackens the silver, and also blackens test-paper containing

acetate of lead. If selenium is present, this reaction cannot be used. To distinguish a sulphate from a sulphide, make a bead of soda on a platinum wire, take up some of the substance to be tested, and heat in the O. F. The crushed bead treated as above will now blacken silver in case of a sulphide, but will show no reaction in case of a sulphate.

The following delicate test in the wet way, given by von Kobell, answers well in most cases: A small quantity of the powdered mineral sample, and an equal volume of iron powder* (*Ferrum pulveratum*, or *alcoholizatum* of the druggist) are put into a glass cylinder 2½ inches high and 1 inch in diameter, and barely covered with hydrochloric acid (1 vol. concentrated acid and 1 vol. of water). A strip of filtering paper, previously dipped into sugar-of-lead solution is fastened to a cork, and the mouth of the cylinder closed with it. In about one minute the paper will be blackened by the sulphide of lead thus formed, if any sulphur is present.

A dilute solution of ammonium molybdate with an excess of hydrochloric acid is colored fine blue by a small quantity of sulphuretted hydrogen or of sulphides dissolved in water. One of the most sensitive tests for sulphur is that of Prof. J. D. Dana. Heat B. B. in the R. F. any sulphide or sulphate, or any powdered mineral containing sulphur, upon charcoal with soda. Put the fused mass into a watch-glass, moisten with a drop of water, and add a particle of a crystal, not larger than a pin's head, of the sodium nitroprus-

* Iron filings, free from rust, are pounded in an iron mortar; first sifted through a fine sieve, and afterwards through linen.

side (or of the corresponding potassium salt); there will be a magnificent purple color displayed at once, but disappearing after some time. Vapors are tested for hydrosulphuric acid (H_2S) by conducting them into an ammoniacal solution of sodium nitroprusside.*

A glass made B. B. of soda and silica becomes red, or orange, when sulphur is present.

When soda is fused on charcoal in the R. F. with any compound of sulphur (sulphide or sulphate), *sulphide of sodium* is produced, and, if much sulphur is present in the sample, the fused mass will show the characteristic color of the "*hepar*" (*Hepar sulphuris*, or liver of sulphur), this being an old term for the higher sulphides of the alkalies, having a liver-brown color.

TANTALUM.—See Niobium.

TELLURIUM.—1. Tellurides, heated in the open glass tube, give a white or gray sublimate, fusible B. B. into colorless, or nearly colorless, drops. On charcoal, they give a white coating, and color the R. F. green-blue.

2. When a compound containing tellurium is tritur-

* If this test for sulphur is made with any organic substance, as pairings of nails, hair, albumen, etc., the carbonate of sodium should be mixed with a little starch-powder, which appears to prevent the loss of any of the sulphur by oxidation. On winding up a hair four inches long, by coiling it around one point of a platinum support, moistening it and dipping it into the mixture of carbonate of soda with starch, and then heating by the blowpipe, the fused mass will give with the nitroprusside an unmistakable action indicative of sulphur. By careful management perfectly satisfactory results may be obtained from a piece of hair less than an inch long. For theoretical deductions concerning *nitro-ferricyanides* or *nitroprussides* consult Qualitative Chemical Analysis, by Professors Prescott and Johnson, 6th edition.

ated with soda and charcoal-dust and fused in a closed tube, then allowed to cool, and a little hot water dropped into the tube, the water assumes a beautiful purple color, owing to the dissolved telluride of sodium.

3. Tellurium compounds, when gently heated in a matrass with an excess of concentrated sulphuric acid, impart to it a purple color, which disappears on the addition of water, when a blackish-gray precipitate is formed.

Consult Bunsen's flame reactions, p. 119, and Table A.

THALLIUM is a very rare element, found in crookesite and lorandite, both very rare. Its compounds impart an intense pure green color to the flame. Seen through the spectroscope, the thallium flame shows only one strong band in the green.

THORIUM is a rare element found in thorite and associated with cerium in a number of minerals. Its oxide, ThO_2, is yellow when hot, white when cold. Sulphuric acid dissolves the oxide; its chloride and nitrate are soluble in water. Oxalic acid produces a precipitate (distinction from Al and Be) not soluble in excess nor in dilute HCl, but soluble in ammonium acetate containing free acetic acid (distinction from Y and Ce). HF precipitates the fluoride, at first gelatinous, then pulverulent, insoluble in water and HF (distinction from Al, Be, Zr, Ti). Potassium sulphate in concentrated solution precipitates Th slowly, but the precipitation is complete (distinction from Al and Be). Alkali hydrates and ammonium sulphide precipitate thorium as white hydrate insoluble in excess, even of fixed alkali hydrate (distinction from Al).

TIN.—In the metallic state, this is recognized by its peculiar physical properties. In nature it is found as an oxide, SnO_2 (cassiterite) and as sulphosalt, Cu_2FeSnS_4 (stannite). B. B. oxide of tin is slowly dissolved by borax to a transparent glass, which is transparent on cooling. With soda or cyanide of potassium on charcoal it is easily reduced with a hot blue reducing flame and steady blowing; and if borax also be added, a very minute quantity of tin may be detected when present in other minerals. The tin rarely unites in one globule, and the fused mass must be crushed and washed to show the metal.

Sulphides containing tin must first be roasted, and the roasted mass treated with a mixture of soda and borax in R. F., the product being bright metallic tin, which can be further tested. On charcoal in the O. F. it forms oxide, that "glows" strongly, and appears yellowish while hot, but becomes white on cooling. Exposed to the R. F. the molten metal retains it bright aspect, but volatilizes and gives the coating of oxide on the charcoal near the point of heating. This oxide moistened with cobalt nitrate and again ignited assumes a bluish-green color.

Tin dissolves in concentrated HCl with evolution of hydrogen, forming stannous chloride, $SnCl_2$, corresponding to stannous oxide SnO; in concentrated *aqua regia* it is easily dissolved to stannic chloride, $SnCl_4$; nitric acid, somewhat diluted, rapidly converts it to metastannic acid, insoluble. Concentrated sulphuric acid dissolves it with evolution of SO_2, to stannous sulphate, $SnSO_4$. Of the stannous salts, the chloride, $SnCl_2$, is the most used; soluble in water and HCl, absorbing oxygen in

the air, and separating oxide, or oxy-chloride. H_2S precipitates, from neutral and acid solutions, brown stannous sulphide, SnS, scarcely soluble in ordinary $(NH_4)_2S$, but more readily soluble in yellow sulphide of ammonium.

Stannous salts are oxidized to *stannic* salts by many oxidizing agents. They are themselves powerful reducing agents.

Stannic oxide, or anhydride, forms two well-marked hydrates or acids: *stannic acid*, and *metastannic* acid, both H_4SnO_4, and H_2SnO_3. *Stannic acid* is formed by precipitating *stannic* salts with alkalies; *metastannic* acid, by the action of nitric acid, sp. gr. 1.35, on tin. Stannic acid is insoluble in water, but it readily forms soluble stannic salts with HCl, H_2SO_4, and HNO_3; and also soluble alkaline stannates with the alkaline hydrates, other stannates being insoluble. Metastannic acid is insoluble in acids but decomposed by HCl, and does not form metastannates.

The stannic oxide, hydrate, sulphide, and phosphate are insoluble in water.

The alkaline hydrates, carbonates, and barium carbonate, precipitate, from solutions of stannic salts, stannic acid, H_4SnO_4, which is white and soluble in an excess of fixed alkaline hydrates and carbonates, but insoluble in ammonium hydrate and carbonate (distinction from antimony).

Copper and tin are separated by treating with strong nitric acid until all the metal is oxidized; the whole is then evaporated, to get rid of most of the acid, and hot water added, when all the metastannic acid (and a trace of copper) can be filtered off; from the filtrate

copper can be thrown down with caustic potassa at a boiling heat as *black oxide*. Should lead, zinc and iron be present at the same time, we proceed as follows: After the metastannic acid has been removed, we separate the lead with sulphuric acid; the copper is precipitated from the acid solution by H_2S; zinc and iron are separated by boiling with acetate of soda, or by adding an excess of ammonia, when the iron is precipitated. From the solution zinc is thrown down by $(NH_4)_2S$, or, in the absence of ammoniacal salts, by carbonate of sodium at a boiling temperature.

Tin from Bismuth.—To a strong HCl solution of the two metals add an excess of water, when an insoluble white precipitate of oxychloride of bismuth is produced. The tin will remain in solution.

Tin from Antimony.—Advantage is taken of the solubility of the sulphides of tin in oxalic acid. From the solution of the two metals the sulphides are precipitated in the usual manner, oxalic acid added in great excess, *i. e.*, 20 grammes of the reagent for every gramme of tin, so that the acid will crystallize out in the cold. Then heat to boiling, and pass in H_2S for about twenty minutes. No precipitate appears at first; but as soon as the liquid is saturated with the gas the sulphide of antimony begins to fall, and, in a very few moments is completely thrown down.

When a neutral solution of a salt of tin is acidulated with some HCl and brought in contact with metallic zinc, metallic tin is thrown down in the form of scales, or as a gray spongy mass. When this reaction is carried on upon platinum foil, no black spot is produced, which is the case when a salt of antimony is thus treated.

Separation of As, Sb, Sn.—The metals are precipitated as sulphides from an acid solution and redissolved in $(NH_4)_2S$ (to separate them from metals not precipitated from acid solutions and not soluble in $(NH_4)_2S$, if present); then HCl is added, when a yellow precipitate falls; the mixture is slightly heated, the sulphides filtered off and washed. The mixture of sulphides is gradually and slightly heated with concentrated HCl; the yellow residue is sulphide of arsenic; the filtered solution contains Sn and Sb.

The yellow As_2S_3* is dissolved in concentrated HCl with addition of $KClO_3$, the solution saturated with NH_4OH in excess, NH_4Cl and $MgSO_4$ added, the precipitate is $Mg(NH_4)AsO_4$. For further confirmation the precipitate is filtered off, and, after washing, a portion of it is dissolved in nitric acid, neutralized with ammonia, and treated with $AgNO_3$, forming brownish-red Ag_3AsO_4, which is soluble in ammonia and nitric acid.

Titanium.—1. Compounds of titanic acid treated with S. Ph. B. B. dissolve in the O. F. to a clear bead, pale-yellow when hot, and colorless when cold. The strong R. F. now turns the bead yellow while hot, reddish when cooling, and violet when cold (titanous oxide). If iron is present, the cold bead is blood-red to brownish-red, and the violet color only appears when the bead is treated with tin, in the R. F. on charcoal. An excess of iron interferes with the reaction.

The borax bead is colorless hot and cold in O. F. but

*H_2S precipitates the arsenic from an acid solution always as As_2S_3; but by the treatment with yellow $(NH_4)_2S$ it passes into As_2S_5.

becomes smoky or brownish with strong saturation in R. F. when cold.

2. Ignition in the O. F. on charcoal with soda does not reduce titanic acid to the metallic state (distinction from tin).

3. If a substance containing titanium is fused with carbonate of sodium, and the product obtained is dissolved in HCl, and then heated with metallic tin or zinc, the titanic acid is reduced to sesquioxide of titanium, coloring the liquid blue or violet, and finally the violet hydrated sesquioxide separates as a powder, retaining its color. This test may be used in presence of an excess of iron.

4. When the powdered mineral containing titanic acid is fused with 6 to 8 parts of bisulphate of potassium, and the mass dissolved in very little water, and next 5 or 6 volumes more of water added, and the solution boiled, a white precipitate results (titanic acid) which may be further examined with salt of phosphorus, etc.

Native titanic oxide (Rutile) is finely pulverized and fused with 4 parts of its weight of alkaline carbonate. The mass, when treated with water, deposits crystalline titanate of the alkali, which remains along with the iron. This should be digested with concentrated HCl, and the diluted solution boiled with sulphite of sodium, when the titanic acid will be precipitated ; or we may precipitate with sulphate of ammonium, and pour sulphurous acid solution over the precipitated mixture, when the sulphide of iron is dissolved out, and the titanic acid left as a white powder.

TUNGSTEN (*Wolframium*).—This is found in the min-

erals Wolframite $(Fe,Mn)WO_4$; in Scheelite, $CaWO_4$; Stolzite, $PbWO_4$, etc. B. B. the oxides of tungsten impart to the bead of salt of phosphorus in the R. F. at first a dirty green, and then a blue color when cold (if iron be present the bead appears blood-red). With tin the bead, in the presence of iron, turns also blue or green. In the borax bead tungstic oxide dissolves colorless in O. F., but with strong saturation becomes reddish and translucent in R. F. when cold.

The metal resembles iron, is brittle, and with difficulty fusible. Treated with nitric acid, or *aqua regia*, it is converted into anhydrous tungstic trioxide, WO_3, which is a yellow powder, insoluble in water and acids, but soluble in caustic alkalies; when it is heated to 250° C. and a current of hydrogen gas passed over it, it turns to blue oxide, *i. e.*, tungstic trioxide combined with tungstic dioxide, $2WO_3+WO_2$; at a dull-red heat it forms brown tungstic dioxide, WO_2.

When a tungstate is fused with carbonate of sodium, and treated with hydrochloric acid and zinc, a beautiful blue color is obtained (reduction to $W_2O_5=WO_3+WO_2$). When a tungstate is fused with bisulphate of potassium, and the fused mass, consisting of bisulphate of potassium, tungstate of potassium, K_2WO_4, and free tungstic anhydride, is treated with water, a solution of the bisulphate is obtained containing no tungsten, but on pouring this off and extracting with water containing ammonium carbonate a complete solution of the residue is obtained, which furnishes a means of separating tungstic from silicic acids. When a finely powdered tungstate is treated with concentrated hydrochloric acid, and a little nitric acid is added, yellow tungstic acid remains

undissolved, but this is readily taken up by ammonia, and this solution, mixed with hydrochloric acid, and zinc added, assumes a blue color. A quick way to perform this test is to treat the *finely pulverized* mineral with *aqua regia* in a test-tube, boil, and when the tube becomes coated with yellow tungstic anhydride, pour off the acid, add HCl and tin, and heat again, when the liquid at once assumes a sapphire-blue color.

The mineral wolframite, $(Mn,Fe)WO_4$, the author found (confirming Dana's experience) to be sufficiently decomposable by boiling concentrated sulphuric acid to give a colorless solution, which, treated with metallic zinc, becomes intensely blue, like Prussian blue, the color lasting several hours.

URANIUM.—The reactions B. B. with borax and salt of phosphorus lead to its detection. With salt of phosphorus it dissolves to a clear yellow glass, turning to a greenish-yellow when cold. In R. F. this glass assumes a dirty green color when hot, but a beautiful green when cold. Treated upon charcoal with tin, this color becomes a darker green. With borax the bead is in O. F. red-brown when hot and fades to yellow when cold, similar to iron; in R. F. it becomes orange when hot and yellow-green to dirty green when cold. Uranium occurs chiefly in the minerals pitchblende and uranite. It combines with oxygen in several proportions, viz., uranium dioxide, UO_2, and trioxide, UO_3, and these combine to form intermediate oxides, *e. g.*, $U_3O_8 = UO_2 + 2UO_3$. UO_2 is basic, while UO_3 is an acid-forming oxide.

Uranic nitrate, $UO_2(NO_3)_2 + 6Aq$, is prepared by dissolving any of the oxides in nitric acid.

Hydrogen sulphide, in solutions acidulated with HCl, produces no precipitate; sulphide of ammonium produces a chocolate-brown one of *oxysulphide*, $UO_2S + H_2O$, somewhat soluble in an excess, but quite insoluble in yellow sulphide of ammonium (containing more S). In the colorless ammonium sulphide it dissolves to a black fluid. On boiling, black uranous oxide and free sulphur are precipitated, the former insoluble in ammonium sulphide (separation from zinc, manganese, iron, etc.).

Ammonium hydrate and caustic potash produce orange-yellow precipitates, insoluble in an excess of the precipitant. Ammonium carbonate and potassium bicarbonate produce yellow precipitates, readily soluble in an excess of the precipitant, but caustic alkalies precipitate the uranium from these solutions. Carbonate of barium precipitates uranium salts completely in the cold (separation from Ni, Co, Mn and Zn).

VANADIUM.—Vanadates, in the absence of other coloring metallic compounds, may be detected by their reactions with borax and salt of phosphorus before B. B.

In the O. F. with S. Ph. the oxide is soluble to a clear glass, which is dark yellow while hot, light yellow when cold. This bead, when brought into the R. F., assumes a dirty bottle-green color when hot, and a beautiful chrome green color when cold. It is distinguished from chromium by its reaction in O. F. With borax in O. F. the bead is yellow when hot, becoming yellow-green and pale greenish on cooling; in R. F. the bead is similar to that given with salt of phosphorus.

Vanadium forms several oxides, as the trioxide,

V_2O_3, and the pentoxide (vanadic anhydride), V_2O_5. The most important compound from an analytical point of view, is vanadic anhydride. It forms a reddish-yellow powder, fusible at a red heat, forming, when cold, a crystalline mass; which is somewhat soluble in water, to a yellow solution with acid reaction and easily soluble in the stronger acids and in alkalies. The vanadates of the alkalies are all soluble in pure water, but much less so in the presence of other alkaline salts. Hydrogen sulphide, H_2S, or sulphurous anhydride (SO_2), reduces an acidulated solution of V_2O_5 to V_2O_4, which latter remains dissolved with a blue color. Sulphide of ammonium throws down a brown precipitate, soluble in an excess with a brown color; soluble in colorless sulphide of ammonium or in sulphide of potassium with an intense cherry-red color (the reaction is very characteristic, but evanescent). Ferrocyanide of potassium produces a yellow precipitate, which becomes green on exposure to the air, and is insoluble in acids. The acidulated solution of a vanadate of an alkali, when shaken with ether containing hydrogen peroxide, H_2O_2, turns red. V_2O_5, when heated in a current of hydrogen gas, is reduced to V_2O_3, black. This same oxide is formed, as a soluble salt, if a solution of the pentoxide in sulphuric acid is reduced by metallic magnesium. The neutral solutions are brown, the acid ones green. All the lower oxides of vanadium in an acid solution are, with permanganate of potassium, oxidized to vanadic acid, exhibiting with sulphide of ammonium the same deportment as that acid itself. Compounds of vanadium can be fused with soda and saltpeter in a platinum crucible. The fused mass,

when extracted with water, acidulated with concentrated acetic acid, and filtered, forms, upon addition of nitrate of silver, a yellow precipitate. When the fusion is evaporated with HCl, a yellow or brownish-yellow solution is obtained, which, upon addition of protochloride of tin (stannous chloride), turns blue.

YTTRIUM.—Yttria, its oxide, is found in the minerals gadolinite, orthite, yttrotantalite, etc. Yttria gives no color to the beads of borax or salt of phosphorus. From its salts caustic potash, ammonia and sulphide of ammonium precipitate white hydrated oxide $Y(OH)_3$, not soluble in excess. Sal-ammoniac prevents the reaction. Y_2O_3 is a strong base, decomposes salts of ammonia, and attracts greedily carbonic acid from the atmosphere. Carbonate of barium does not precipitate it.

Analysis of gadolinite (silicate of Y, Be, Fe, Mn, Ce, La). After the removal of the silica, and neutralization, oxalic acid precipitates the Y, Ce, La, insoluble in excess, or in very dilute HCl, while the Be, Fe and Mn remain in solution. The separation of Y from Ce and La is executed with concentrated neutral sulphate of potassium solution. The double sulphate, $K_3Ce(SO_4)_3$ is but slightly soluble in water, and quite insoluble in sulphate of potassium solution, and the same is the case with the double sulphate, $K_8La_2(SO_4)_7$. Hence these are precipitated, while from the solution the yttrium hydrate, $Y(OH)_3$, is thrown down by ammonia and is determined as such.

ZINC.—Oxide of zinc with borax gives a clear glass, which is milk-white on flaming; or, with more assay, is enamel-white on cooling In the inner flame, on charcoal, fumes are given off and a white coating sur-

rounds the assay. With soda on charcoal the ores, even when containing little zinc, afford the peculiar bluish flame of burning zinc, and white oxide is deposited on the charcoal. With cobalt nitrate solution this coating, after ignition and cooling, assumes a green color, while tin gives a bluish-green.

From solutions of zinc all the alkali hydrates, including ammonia precipitate white hydrate of zinc, $Zn(OH)_2$, soluble in an excess, but reprecipitated, especially from the ammoniacal solution, by boiling.

Hydrogen sulphide precipitates a part of the zinc from neutral solutions of its salts with mineral acids and, the whole from the acetate (*i. e.*, sulphide of zinc is not soluble in acetic acid). Alkali sulphides—as sulphide of ammonium $(NH_4)_2S$—throw down all the zinc as sulphide, both from its salts with acids, and from its soluble combinations with alkalies. Pure sulphide of zinc is white.

ZIRCONIUM occurs in nature in zircon and several other rare minerals. B. B. zirconia is infusible; when strongly heated a very brilliant light is given out.

Zirconium forms only one compound with oxygen viz., ZrO_2, which yields salts with acids, the sulphate being with difficulty soluble, the chloride, $ZrCl_4$, volatile. Fluoride of zirconium is soluble in water (distinction from thorium) and yields with fluoride of potassium a double salt, K_2ZrF_6, with difficulty soluble in water. ZrO_2, fused with soda, liberates CO_2, forming a scarcely soluble sodium compound, the composition of which is variable; the simplest, Na_4ZrO_4, is produced by the action of an excess of soda. Compounds containing zirconium, generally silico-zirconates, are decomposed for analysis

by fusion with sodium carbonate or with hydrogen potassium fluoride.

Caustic alkalies, ammonia, and sulphide of ammonium, throw down hydroxide, $Zr(OH)_4$, not soluble in an excess of caustic alkalies or in sal-ammoniac (distinction from aluminium and beryllium), but soluble in carbonate of ammonium. $Zr(OH)_4$ obtained in the cold is easily soluble in acids, but that produced at a higher temperature, or the ignited oxide, is with difficulty soluble (requiring two parts of concentrated sulphuric acid to one of water). Potassium, sodium and ammonium carbonate precipitate zirconium carbonate, white and flocculent, which redissolves in excess of potassium carbonate and bicarbonate, and in ammonium carbonate, but is reprecipitated on boiling. Neutral sulphate of potassium precipitates, in the cold, white $K_4(SO_4)_4$, insoluble in an excess, but soluble in cold HCl (distinction from Al and Be). The precipitated salt produced at a higher temperature is insoluble in HCl (distinction from Th and Ce). Oxalic acid yields an oxalate insoluble in an excess, but soluble in HCl, and in oxalate of ammonium (distinction from thorium).

Analysis of zircon: $ZrSiO_4$ is fused with soda. The mass is treated with water, which dissolves silicate of sodium, and leaves behind a crystalline powder of sodium zirconate, which, after washing with more water, is dissolved in HCl, and from which solution NH_4OH throws down $Zr(OH)_4$. From ferric iron, zirconium is separated with oxalic acid or hyposulphite of sodium. Turmeric paper dipped in a solution of zirconium in HCl or H_2SO_4, and dried assumes a brownish-red color. In presence of TiO_2 reduce the solution with zinc before testing.

CHAPTER IX.

FUSION AND FLUXING.

THE term "fusion" is applied to the conversion of a id substance into the fluid form by the application of at; fusion being most frequently resorted to for the rpose of effecting the combination or decomposition bodies. The term "fluxing" is applied to the pro-ss in cases where substances insoluble, or difficult of lution, in water and acids, are, by fusion in conjunc-n with some other body, modified or decomposed in ch a manner that the newly-formed compounds will bsequently dissolve in water or acids. Fusion and ixing are conducted either in porcelain, silver or plati-m crucibles, according to the nature of the com-und. The crucible is supported on a triangle of me-um stout platinum-wire, resting on the ring of a retort and. (See FIG. 70, p. 47.)

Resort to fluxing is especially required for the analy-s of the *sulphates of the alkaline earths*, and also for at of many silicates. The flux most commonly used carbonate of sodium or carbonate of potassium, or, tter still, a mixture of both in equal atomic propor-on, *i. e.*, 13 parts of pure dry carbonate of potassium e mixed with 10 parts of pure *anhydrous* carbonate of dium.*

*The mixture is kept in a well-stoppered bottle.

Silicates are fused with about 4 to 5 parts of the alkaline mixture mentioned, or, still better, with carbonate of sodium alone, provided the operation is carried on with Bunsen's blast lamp or a wind furnace. A basic alkaline silicate is formed, which, being soluble in water, may be readily separated from such metallic oxides as it may contain in admixture. From this basic alkaline silicate, hydrochloric acid separates *the silicic acid as hydrate.* If a fixed alkaline carbonate is fused together with sulphate of barium, strontium or calcium, there are formed carbonates of the alkaline earths and sulphates of the alkalies. In the new compounds both the base and the acid of the originally insoluble salt may now be readily detected. However, we do not employ carbonate of potassium, nor carbonate of sodium, separately to effect the decomposition of the insoluble silicates and sulphates ; but we employ for this purpose the above-described mixture of both, because this mixture requires a far lower degree of heat than either of its components alone, and hence the operation may be conducted over an alcohol lamp with an argand burner or a Bunsen gas-burner. The fusion with alkaline carbonates is always effected in a platinum crucible provided no reducible metallic oxides be present, which would ruin the crucible.

In cases where alkalies are present in the mineral submitted to analysis, we employ hydrate of barium* for its fusion. Upon fusing silicates together with about four parts of hydrate of barium, a basic silicate

* Hydrate of barium fuses at a gentle red heat without losing its water.

of barium is formed, and the oxides are liberated. If the fused mass is treated with hydrochloric acid, the solution evaporated to dryness, and the residue digested with hydrochloric acid, the silicic acid is left behind, and the oxides pass into the solution in the form of chlorides. As a flux to test silicates for alkalies, hydrate of barium is preferable to carbonate or nitrate of barium, since it does not require a very high temperature for its fusion, nor does it cause any spurting in the fusing mass from the disengagement of gas, as is the case with the nitrate. The operation is conducted in a silver or platinum crucible. The mineral subjected to fusion must in every case be very finely pulverized in an agate mortar. A mixture of ammonium chloride and pure calcium carbonate (precipitated chalk) is also used in fusions of silicates for alkalies.

Deflagration.

In a very general sense "*deflagration*" signifies a process of chemical decomposition attended with more or less detonation or explosion. It is here used in a more restricted sense to designate the oxidation of a substance in a dry way at the expense of the oxygen of another substance mixed with it, usually a nitrate or a chlorate, *e. g.*, saltpeter, potassium chlorate. Connected with this process is a sudden or violent combustion, attended with a very lively incandescence. Deflagration is resorted to, either to produce the desired oxide—*e. g.*, tersulphide of arsenic is deflagrated with nitrate of potassium to obtain arseniate of potassium—or it is applied as a means of proving the presence or absence of a certain substance. Thus salts are tested for nitric

or chloric acids by fusing them with cyanide of potassium, and observing whether this process will cause deflagration * or not.

To attain the former object, the perfectly dry mixture of the substance under investigation and of the deflagrating agent is projected in small proportions into a red-hot porcelain crucible. With very small quantities the process is best conducted on a piece of platinum foil, or in a small platinum spoon.

On the use and Preservation of Platinum Vessels.

Platinum apparatus being very expensive, should be handled with great care and kept polished, *i. e.*, by gently rubbing with moist sea-sand (the rounded grains of which do not *scratch* the metal); by fusing borax upon the coated surface, or by digestion with nitric acid, and lastly polishing again with sea-sand.

1. *Platinum* is not attacked at any temperature by nitric, hydrochloric, or sulphuric acid, but dissolves in nitro-hydrochloric acid, though less readily than gold.

2. *Free chlorine* and *bromine* attack platinum at the ordinary temperature; also free sulphur, phosphorus, arsenic, selenium, and iodine attack ignited platinum. Hence the fusion of sulphides, sulphates, and phosphates with reducing agents (carbon, etc.) is injurious or fatal to platinum vessels. The ignition of organic material containing phosphates is also injurious.

* B. B. deflagrations of minute quantities, *e. g.*, common and Chili saltpetre, chlorate of potassium, etc., are executed on charcoal. If we place upon the fused mass a piece of moistened red litmus paper it turns blue (alkaline carbonates), and a drop of HCl causes effervescence (CO_2).

3. *The heating* of ferric chloride, and the fusion of bromides, and iodides affect platinum to some extent.

4. *The alkali hydrates** (not their carbonates) and the *alkaline* earths, especially baryta and lithia when ignited with platinum in the air, gradually corrode platinum vessels. The nitrates of the alkalies or alkaline earths are also detrimental.

5. All *metals* which may be reduced by fusion, especially salts of bismuth, lead, tin, and all metallic compounds mixed with reducing agents (cyanide of potassium, etc.), including the alkalies and earths, form fusible alloys at a high temperature with platinum. Oxides of mercury, lead, bismuth, tin, antimony, zinc, copper, nickel, are, at white heat, rapidly reduced, unite with the platinum, and corrode it.

6. Platinum crucibles should not be supported on charcoal in the furnace, but packed in magnesia in an outer crucible of clay. The reducing gases of a Bunsen burner even have an effect upon platinum, probably forming a carbide, and causing blisters, with liability to cracking. Care should be taken therefore to avoid using the inner flame of the Bunsen burner when heating platinum crucibles.

Cracks and holes in platinum crucibles may be repaired with gold solder, but such vessels cannot afterwards be exposed to a high heat. Platinum vessels can however be renovated by welding, without use of solder. This is, of course, best performed by the maker.

* Caustic alkalies must be fused, or evaporated in silver crucibles. These can only be used at temperatures below full redness, and must not come in contact with sulphur or be heated over coke, coal, or gas, or other fuel containing sulphur.

PART II.*

CHEMICAL DETERMINATIVE MINERALOGY.

BASED UPON FRANZ VON KOBELL'S "TAFELN ZUR BESTIMMUNG DER MINERALIEN," BUT ENTIRELY REWRITTEN AND REARRANGED FOR THIS EDITION BY THE EDITOR.

CHAPTER X.

ON THE DETERMINATION OF MINERALS BY MEANS OF SIMPLE EXPERIMENTS WITH THE BLOWPIPE, AIDED BY HUMID ANALYSIS.

INTRODUCTION TO THE TABLES.

The following tables are intended to assist in the discovery and to facilitate the determination of minerals by the most plain and reliable methods of examination. They are based upon a few simple experiments with the blowpipe or with chemicals in the wet way, in which latter the substance, if not already fluid, is first brought into the liquid state and is then acted upon by chemical reagents in the form of a solution. These experiments soon lead to a group containing a few species, among which is to be found the mineral sought, its name and usual composition. The species under examination can generally be distinguished from others in the same group

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by some of its chemical characters. In any case where uncertainty or doubt might arise on account of similarity in the chemical reactions of two species, their physical properties as given in Part III should be consulted, or reference be made to some work on descriptive mineralogy as Dana's Text Book of Mineralogy.

In order to perform successfully all the manipulations here required, it is only necessary to be acquainted with the use of the blowpipe, and also with the manner of making some simple solutions and precipitations.

It is expected that these pages will be especially useful to those who have neither the time nor the inclination to devote themselves to the study of larger works on mineralogy, but to whom the determination of some few minerals is often a matter of interest. For that reason it may be acceptable to the chemist, the miner, the farmer, and the mechanic.

When an individual wishes to determine any mineral, the arrangement is such that he will be constantly directed by the divisions to the test which he must make. After noting the *luster of the mineral*, there is generally required a *single fusion of the sample*, either alone or *with soda;* then one trial by solution, and a few precipitations, when the object sought is attained. It is *absolutely essential*, however, that the tests required should all be made *in the order given;* any departure from this rule is liable to result in failure to determine the species. Any one who will follow the directions here given, and execute the tests with accuracy, will soon become acquainted with many reactions, and by a short practice he may acquire the ability to determine minerals with facility and certainty. Where errors

would be most likely to occur in the examination, they are avoided by the arrangement of the divisions, *e. g.*, some minerals have both a *metallic* and *non-metallic* luster; some fuse *under* or *above* 5, according to the skill of the operator. As these minerals might appear of doubtful limit, they are mentioned in both divisions.

Physical Properties of Minerals.

I. Luster. In the group of *minerals with metallic luster* are placed only those which are perfectly opaque (most of them have dark streak). A thin splinter held between the eye and the light and examined with a pocket lens, must show no translucency on the edges, when it is considered as having *metallic luster;* otherwise as without it. Many *earthy* minerals with *light colored streak* seem to be opaque, but they are included under the head of *minerals with non-metallic luster.*

II. Fusibility.

The following is the scale of fusibility:—

1. Stibnite (antimony glance). Fusible in large pieces in the candle or lamp flame.

2. Natrolite. Fusible in splinters in the luminous candle or lamp flame. S. L. Penfield prefers chalcopyrite for No. 2, fusible in a medium size piece (1.5 mm.) in the candle flame.

3. Almandite. Alumina-iron garnet does not fuse in a candle flame like the preceding; but B. B. fuses easily, even in medium size pieces.

4. Actinolite. B. B., easily fusible in rather fine splinters, and the edges of medium size pieces rounded.

5. Orthoclase. B. B., only fusible to a globule in very fine splinters.

6. Bronzite. B. B. becomes rounded only on the finest points and the sharpest edges.

Splinters or fragments of these minerals are kept on hand, and their fusibility compared with that of samples similar to them in size and edges.

Trials of fusibility should be made in the forceps, and minerals difficult of fusion should be employed in thin splinters, since these might fuse on the edges, while an obtuse piece might lead to the conclusion that the mineral is infusible. Nor should the sample be regarded as infusible until it has been heated just beyond the extremity of the blue flame where the heat is most intense. Minerals which are infusible often glow and emit a bright light; this is characteristic of oxides of Ca, Mg, Zr, Th, etc.

Minerals which decrepitate strongly (like common salt) are finely pulverized, moistened with water and placed on charcoal; by heating, the particles become sintered (if the sample be fusible), so that the mass may be taken up in the forceps and further heated in the flame.

Metallic looking minerals had best be tested for fusibility on *charcoal* first, before trying in the forceps; thus avoiding the alloying of arsenides, sulphides, etc., with the platinum tips. With care, however, any mineral may be tested in the forceps.

III. HARDNESS. For the scale of hardness that of Mohs is adopted, which is as follows, viz:—

1. Talc, common foliated, light-green variety.
2. Gypsum, the crystallized variety.
3. Calcite (calc-spar), transparent variety.
4. Flour-spar, crystallized variety.

5. Apatite, transparent variety.
5.5. Scapolite, crystalline variety.
6. Orthoclase, white, cleavable variety.
7. Quartz, transparent variety.
8. Topaz, transparent crystal.
9. Corundum (sapphire), cleavable variety.
10. Diamond.

Trials of hardness are made by taking individuals of the scale and attempting to scratch the mineral under examination. A few trials will give sufficient experience in the use of this scale; but *exact* determinations of hardness by the scale are rather difficult.

Sharp corners must be used in scratching, and particular care should be taken in this, as in all other cases, that *impurities* do not come in to modify the result; thus a grain of quartz in some of the impure varieties of galena, if it happened to come upon the corner which is used, would make the mineral appear quite hard, and without proper precautions many such errors may occur.

IV. COLOR. Great care must be taken in forming any conclusions from the colors of minerals. In minerals of metallic luster the color is generally constant and often very characteristic, in some of the non-metallic species the same is true, but experience will teach how greatly the colors of non-metallic minerals vary, and varieties are constantly found differing in color from all that were previously known. Hence, especially in non-metallic minerals, the color which is given should only be regarded as an aid, or suggestion in the determination.

V. STREAK. The *streak* of a mineral is the color of

the powder obtained by scratching it with a knife, or better, if not too hard, by rubbing it upon a piece of unglazed porcelain, or *streak plate.* Minerals too hard for this may be tried upon the piece of corundum of the *hardness scale.*

VI. Specific Gravity.

Determination of the specific gravity may be performed by use of an ordinary good balance and weights. The specific gravity of a mineral is its weight compared with that of an equal volume of water, which is taken as a unit of comparison.

The direct comparison by weight of a certain volume of water with an equal volume of a given solid is not often practicable. By making use, however, of a familiar principle in hydrostatics, viz., that the weight lost by a solid, immersed in water, is equal to the weight of an equal volume of water—that is, the volume of water it displaces—the determination of the specific gravity becomes a very simple process.

The weight of the mineral in the air (w) is determined by weighing with the balance in the usual manner, then the weight in water is found (w'), when the loss by immersion, or the difference of the two weights ($w—w'$) is the weight of a volume of water equal to that of the mineral. Finally, the quotient found by dividing the first weight (w) by that of the equal volume of water as determined ($w—w'$), gives the specific gravity (G). That is to say: $G.=\frac{w}{w—w'}$.

For example, the weight of a fragment of *quartz* is found to be 4.534 grammes. Its weight in water is

2.817 grammes, and therefore the loss of weight, or the weight of an equal volume of water = 1.717. Consequently the specific gravity $= \frac{4.534}{1.717}$ or 2 641.

The mineral is first accurately weighed on a good balance, then suspended from one pan of the balance by a horse-hair, silk thread, or, better still, by the finest possible platinum wire, and immersed in a glass of distilled water conveniently placed beneath. The platinum wire may be wound around the specimen, or, where the latter is small, it may be coiled at one end into a little spiral support. While thus suspended, the weight is again taken with the same care as before.

FIG. 122.

Since the density of water varies with its temperature, a standard temperature must be selected for these experiments; in order to obtain uniform results: 15° C. (60° F.) has been generally adopted.

If the mineral is not solid, but pulverulent or porous, it is best to reduce it to small fragments, and weigh it in a little glass bottle, shown above (Fig. 122).* This bottle has a stopper which fits tightly, and consists of a capillary tube, with a very fine opening. The bottle is filled with distilled water, the stopper inserted, and the overflowing water carefully removed with a soft cloth. It is now weighed, and also the mineral whose density is to be determined. The stopper is then re-

* These glass bottles are capable of holding exactly a thousand grains, or two hundred grains, or any known weight of distilled water.

moved, and the mineral, in small fragments, inserted with care, so as not to introduce air-bubbles. The water which overflows on replacing the stopper is the amount of water displaced by the mineral. The weight of the bottle with the inclosed mineral is determined, and the weight of the water lost is obviously the difference between this last weight and that of the filled bottle and the mineral together, as first determined. The specific gravity of the mineral is equal to its weight in air, divided by the weight of the equal volume of water thus determined.

Where this method is followed with sufficient care, especially avoiding any change of temperature in the water, the results are quite accurate. It is necessary, however, to make all weighings at a constant temperature, or observe the temperature in each case and reduce to a constant temperature. An improved specific gravity bottle or *pycnometer* has a thermometer introduced instead of a stopper, and in addition a fine tube parallel to the neck, and closed by a cap with a capillary perforation. In using this instrument (the weight of water that it will contain at the standard temperature, *e. g.*, 60° F = 15.6° C. being known or determined) it is filled with water, cooled below the standard temperature, the weighed mineral fragments introduced and the thermometer placed in the neck. When the temperature rises to the standard, the small side tube is wiped dry and the cap placed over it. The apparatus may now be allowed to come to room temperature, and the expanding liquid will all be retained in the cap at the end of the fine tube. The calculations are the same as for the other style of apparatus.

If a mineral is soluble in water, it is weighed in a liquid in which it is insoluble, and of which the specific gravity is known. The specific gravity is then readily calculated.

Example 1.—50 parts of rock-salt (w), when weighed in spirits of turpentine, displace an amount, the weight of which is equal to 19.53 parts. The specific gravity of spirits of turpentine is to that of water as 0.872:1; hence, we find that $0.872:1 = 19.53:(w—w')$, and hence

$w—w' = \frac{19.53}{0.872} = 22.396$, *i. e.*, the weight of an equal volume of water.

Since $G = \frac{w}{w—w'} = \frac{50}{22.396} = 2.232$, the latter number, 2.23, expresses the specific gravity of rock-salt.

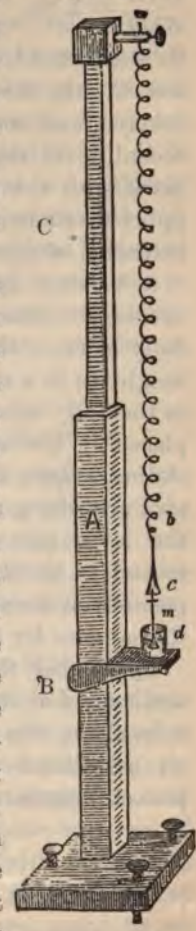
Example 2.—A substance soluble in water was weighed in oil, and its specific gravity, compared with the oil, as 2.6, the specific gravity of the oil was 0.87; then $2.6 \times 0.87 = 2.262$, the specific gravity of the substance.

The specific gravity of minerals is easily taken by means of Prof. Jolly's spring-balance. (Fig. 123). A wire wound in a spiral form is suspended at a, and has attached at its lower end, b, two pans c and d. The pan, d, dips into water. The vessel containing the water in which the pan is suspended is placed upon a shelf, which may be moved up or down on the standard of the balance. A mark at m shows the extension of the spiral on the mirror scale, which is also attached to the standard. In reading, the mark is made to cover the reflection on the mirror.

weights increasing a tenth of a
ne are added successively to
an in the air, it is found that
xtension of the wire is in pro-
n to the weight added. Coni-
wound wire, with its greatest
ter at *a*, and its smallest at *b*,
precisely the relation between
ze of the load and the extension
spiral.

e manner of using the balance
xtremely simple. Before the
ance is placed on the pan, the
of the mark is observed on the
Three readings are made:
with empty pan; second, with
ance placed on the upper pan;
he third, after placing the same
ance on the pan under water.
difference between the first two
the absolute weight expressed
visions of the scale, and the
ence in the last two gives the
t of the displaced water. The
ent of these differences is, there-
the *specific gravity*. If the mark
the empty pans stands at 64.2,
with the substance placed in
pper pan at 275.3, and with the
substance in the lower pan at
, then the absolute weight is
$-64.2 = 211.1$, and loss of weight in water

Fig. 123.



is $275.3 - 220.8 = 54.5$. The specific gravity will be $\frac{211.1}{54.5} = 3.85$. As is shown in the drawing, the shelf, B, is attached to the standard, A. The movable standard, C, has the same length as A; can be raised or lowered, and made fast at any point. C is drawn out according to the length of the spiral, so far that the mark with the pans empty stands opposite one of the upper divisions of the scale, which, to show the whole extension of the spiral, must be at least 600 mm. long.

A balance made of a strip of wood poised upon a needle, the shorter arm carrying two pans as in the Jolly balance, the longer graduated and with a sliding weight as in a steel-yard, may be used as conveniently as the Jolly balance. The fragment of mineral is first placed in the upper pan and counter-poised by the sliding weight, the position of the weight on the graduated arm being noted. The mineral is then placed in the lower pan under water, and the sliding weight moved in until it is counter-poised again, when its position on the scale is again noted. The calculation is the same as for the Jolly balance.

By making the scale of even thickness throughout, and poised at the middle point upon a thread through a fine hole, this balance may be made self-reading and all calculation avoided. This may be made into a pocket instrument for prospectors.*

VII. Pyro-electricity.

Electricity is developed in some minerals by heat,

* See Appendix; also Pollok, Trans. Amer. Inst. Mining Engineers, XXIX, p. 281

whereby some light substances are attracted, such as deer's hair, or fibers of wool and cotton.

In determining whether a crystal is positively or negatively electrified, mistakes may easily happen, which may, however, be avoided by using a cat's hair fastened by wax to a cork or piece of tube, and which drawn between the fingers becomes positively electrified. It is attracted to the end of the crystal that is negatively electrified and repelled by the positively electrified end. If a mixture of powdered sulphur and red lead be dusted over the electrified mineral, the red lead is attracted to the negatively electrified end, and the sulphur to the positively electrified end. The mixture should be agitated before or when using.

VIII. Optical Investigation of Minerals.

When a mineral is transparent, a polarization microscope may be used for its investigation. Descriptions of these characters and the methods employed in their investigation may be found in such works as Dana's Text-Book of Mineralogy, and Rock Minerals, Iddings.

IX. Altered Reactions of Impure Minerals.

It is scarcely necessary to remark that the reactions usually mentioned relate only to pure or homogeneous specimens. When a mineral is presumed to be impure, we must take into consideration its adulterations and judge of the reactions accordingly. Some varieties of wollastonite, for example, effervesce with acids, and also react alkaline after fusion; which reactions do not belong properly to this material, but are caused by an admixture of calcite or other carbonate.

X. Crystallization and Cleavage.

Crystallization, if distinct, will often aid very materially in determining the identity of a mineral.

A discussion of crystal morphology or the crystal forms assumed by minerals will be found in Chapter II, p. 6.

The crystallization may often be determined by observation of the *cleavage*, where the forms of the crystals are not well developed, and the cleavage is often a very distinctive character, even when the crystals are well formed. It may be defined as the tendency of the mineral to part in certain definite directions, along plane surfaces. It is evidently a function of the cohesion of the mineral, and the *cleavage plane* is normal to a direction of minimum cohesion in the mineral.

In the isometric system, when the crystal axes are the directions of minimum cohesion, the cleavage is *cubic* (100); when the crystal axes are directions of maximum cohesion, the minimum cohesion directions are either equally inclined to all three axes or normal to the octahedron planes, producing *octahedral* cleavage, (111); or, on the other hand, the direction of minimum cohesion is normal to one axis and equally inclined to the other two, producing *dodecahedral* cleavage, (110). These are the only cleavages observed in the isometric system. Examples are: Galenite, fluorite, sphalerite.

In the *tetragonal system* the principal or vertical axis is the direction of minimum or maximum cohesion. In the former case the cleavage is basal (001), in the latter it is *prismatic* (100) or (110), or pyramidal (111).

In the *hexagonal system* the cleavage, in the *hexagonal section, is* either *basal*, or *prismatic* or *pyramidal*, as in

the tetragonal system. In the *trigonal section* it is *basal*, or *prismatic*, or *rhombohedral.*

In the *orthorhombic system* the cleavage is parallel to any pinacoid or to all three, *pinacoidal*, *basal*, *etc.*, or it is *prismatic* or *domatic*, the prisms and domes being interchangeable.

In the *monoclinic system* the only fixed axis is the orthoaxis. If this is the direction of minimum cohesion, the cleavage is *clinopinacoidal*, but where the minimum cohesion is normal to the base or to a prism plane the cleavage is *basal* or *prismatic.* As the clinodome, hemipyramid and prism are interchangeable, cleavages have been recorded parallel to these planes also. In the same way cleavages may be parallel to the orthodome or the orthopinacoid, which are interchangeable with the base.

In the *triclinic system* as all planes are really pinacoids, cleavages are used to determine the position of the pinacoids, where possible, and are hence recorded as pinacoidal.

Under stress, the layers of molecules of a crystal will sometimes "buckle" and produce planes in which the orientation of the molecules is different from that of the general crystal; these may become planes of separation or shear planes, called *parting planes.* The *parting* along such planes differs from cleavage in that it cannot be produced by fracture except when these planes already exist. The direction of the parting plane is simply and definitely related to the cleavage planes, but they are rarely identical in any given substance.

Decomposition by Acids.

To test whether a mineral is decomposable (soluble) in acids or not, the sample should be pulverized as finely as possible in an agate mortar. It is then treated with tolerably strong acid, for example, hydrochloric acid and water 1:1, and, if necessary, heat is applied. The digestion is carried on in a large test-tube, or a small porcelain dish. In order to see whether *silicates* or many *compounds of the earths*, and the allied *metallic oxides*, have been partially dissolved, we separate the acid by decantation or filtration from the residue, and evaporate a few drops in a clean watch glass, when a residue indicates that the mineral has been attacked; or add *ammonia* in excess, and then a few drops of *phosphate of sodium*, when if these two reagents produce a decided precipitate, it is a sign that decomposition has taken place, but if no precipitate is formed, or but a few flakes appear, the mineral may be pronounced nearly or quite insoluble.

On treating some silicates with hydrochloric acid, 1:1, as above, the silica separates as hydrate in gelatinous lumps; in other cases the jelly only appears on evaporation as the solution approaches dryness. This is best tested in a small evaporating dish. In other cases, however, the silica may remain after decomposition in the acid as a fine powder, and the decomposition is best made out by testing as indicated in the preceding paragraph. Many silicates gelatinize when previously fused, *e. g.*, garnet, vesuvianite, etc. For this purpose several splinters, or small pieces of the sample are fused B. B., then wrapped in paper and crushed to powder on a steel anvil, and then ground still finer in an agate mortar.

This fine powder is brought into a reagent tube or porcelain dish, some hydrochloric acid added, and the whole boiled until the acid is evaporated, when gelatinous lumps remain behind; or a gelatinous mass is produced in the vessel. If this is evaporated to dryness and then taken up with water and HCl, it may be filtered, and the filtrate be further tested with ammonia, oxalate of ammonium, etc., for alumina, lime, etc., that might be present.

EXAMPLE.

The following example will illustrate the method employed in determining the minerals by the tables. Let us suppose that we have bornite, or variegated copper pyrites to determine upon.

The mineral has *metallic luster;* heated B. B. it fuses without giving off visible fumes or producing a coating on the charcoal. In the oxidizing flame we can perceive the odor of *sulphurous acid* but no other odor; and the sample, when heated on charcoal with carbonate of sodium, forms *hepar* (sulphide of sodium) which, when crushed upon a silver coin and moistened, forms a black or brownish spot. From this it follows that the mineral is a *sulphide* and must be looked for under Group I, Class II, Division 5, p. 240. Trying the tests given under the sections lettered *a*, *b*, *c*, *d*, in order, we find that the mineral gives a *copper* reaction, and hence comes in section *d*. The color of the freshly broken mineral is *pinchbeck bronze-brown;* it shows also blue, greenish and purple tarnish. The only mineral showing these colors in this section is BORNITE, p. 242. The *iron* in *bornite* may be demonstrated by dissolving the

mineral in HNO_3 and adding an excess of ammonia, when the copper dissolves, forming a deep blue solution, and a reddish brown precipitate of *ferric hydrate* falls.

On beginning the study of determinative mineralogy, the student ought to exercise great patience and proceed slowly, but surely. When working independently or without direction, it is by far the best way to examine at first well-known species.

Mineral species selected for the study of determinative mineralogy. Von Kobell advises his own students to determine the following list of minerals according to the method before us:

Aluminite,
Alunite,
Anhydrite,
Antimony-glance,
Apophyllite,
Argentite,
Arsenopyrite,
Atacamite,
Barite,
Borax,
Bornite,
Bournonite,
Calamine,
Calcite,
Cassiterite,
Celestite,
Cerussite,
Chalcopyrite,
Chalcocite,
Cinnabar,
Cryolite,
Cuprite,
Datolite,
Diallogite,
Dolomite,
Lapis-lazuli,
Lepidolite,
Lievrite,
Limonite,
Magnesite,
Magnetite,
Malachite,
Manganite,
Molbydenite,
Natrolite,
Niccolite,
Orpiment,
Pectolite,
Psilomelane,
Pyrite,
Pyrolusite,
Pyromorphite,
Pyrrhotite,
Realgar,
Scheelite,
Siderite,
Smaltite,
Smithsonite,
Sphalerite,
Strontianite,
Talc,
Witherite,
Wolfram,
Wollastonite,
Wulfenite.

LES FOR THE DETERMINATION OF MINERALS BY CHEMICAL PROPERTIES.

TO THE GENERAL CLASSIFICATION OR SYNOPSIS OF THE TABLES.

p I.—Minerals with metallic and submetallic luster. Of those minerals whose luster may be doubtful, only such are here included as are perfectly opaque, even on the thinnest edges. Most of them have dark streaks.

lass I.—Native malleable metals and mercury are easily distinguished from others, see page 232. The remaining minerals form the following groups:—

lass II.—Fusible from 1-5, or readily volatile.

Division 1.—B. B., on charcoal evolve the strong garlic odor of **arsenic,** and in the open tube give a coating of As_2O_3 in crystals, page 234.

Division 2.—B. B., on charcoal, or heated in an open glass tube, give the horse-radish odor of **selenium,** page 237.

Division 3.—B. B., on charcoal, a whitish deposit is obtained which tinges the R. F. green; in presence of selenium, greenish-blue. Heated gently in a test-tube with an excess of concentrated sulphuric acid, the latter assumes a purple-red or hyacinth-red color, which upon the addition of water disappears, while a grayish-black precipitate of **tellurium** is thrown down, page 237.

Division 4.—B. B., on charcoal, or in an open glass tube, evolve copious fumes of **antimony oxide,** Sb_2O_3, page 238.

Division 5.—Heated in an open glass tube give off the odor *of burning* **sulphur,** evolving SO_2, which reddens, *and finally* bleaches moistened blue litmus paper.

B. B., with soda on charcoal, yield hepar (sulphide of sodium), which blackens a silver coin when crushed upon it and moistened, but do not give reactions of the preceding divisions, page 240.

Division 6.—Not belonging to the preceding divisions, page 245.

Class III.—Infusible, or fusibility above 5, and not volatile, page 246.

Division 1.—B. B., impart, even in small quantities, to the borax bead in the O. F., the amethystine color of **manganese,** page 246.

Division 2.—Are magnetic, or B. B., on charcoal, become so if perseveringly heated in the R. F.; **iron** compounds, page 247.

Division 3.—Not included, but in some respects related to the preceding divisions, page 249.

Group II.—Minerals without metallic luster.

Class I.—B. B., volatilize easily or are combustible, page 251.

Class II.—B. B., fuse easily between 1-5, and volatilize only partially or not at all, page 252.

Part **A.**—B. B., fused with soda on charcoal yield a **metallic globule,** or when fused alone, in the R. F., form a mass which **is attracted by a magnet.**

Division 1.—B. B., yield with soda alone, or with soda and borax together, a **silver** globule.

Those decomposable by nitric acid yield, when their solution is treated with hydrochloric acid, a white precipitate of chloride of silver, which B. B. on charcoal is easily reduced to metallic silver, page 252.

Division 2.—B. B., with soda, yield a **lead** globule, and with S + KI a yellow coating of lead iodide.

The nitric acid solution gives, upon the addition of sulphuric acid, a white precipitate of sulphate of lead, which B. B. with soda on charcoal furnishes metallic lead, page 253.

Division 3.—In the borax bead give a copper reaction, R. F., moistened with hydrochloric acid, communicate to the blowpipe flame a transient blue color, indicating **copper,** page 255.

Division 4.—B. B., impart to the borax bead a sapphire-blue color (**cobalt**), page 257.

Division 5.—B. B., fused in the forceps, or melted on charcoal in the R. F., give a black or gray metallic mass, attracted by the magnet, but do not belong to the preceding divisions, page 258.

Section i.—Evolve, when fused, a strong arsenical odor, page 258.

Section ii.—Soluble in hydrochloric acid without leaving a perceptible residue, and without gelatinizing, page 258.

Section iii.—With hydrochloric acid form a jelly, or decompose with separation of silica, page 260.

Section iv.—Only slightly attacked by hydrochloric acid, page 262.

Part **B.**—B. B., fused with soda on charcoal give **no metallic globule,** or fused alone in R. F. **do not become magnetic.**

Division 1.—B. B., after fusion and continued heating in the forceps (or when easily fusible, in a platinum spoon), have an **alkaline reaction,** turning the moistened yellow turmeric paper brown,* page 263.

Section i.—Easily and perfectly soluble in water, page 263.

Section ii.—Insoluble or very slightly soluble in water, page 266.

Division 2.—Soluble in hydrochloric acid, some also in water, without perceptible residue; the solution **does not form a gelatinous mass** upon evaporation, page 268.

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ofessor Kenngott has shown that many silicates and other unds, before and after fusion, have an alkaline reaction when re placed on turmeric paper in the form of powder moistened *ater, but they do not show* this reaction when in fragments.

Division 3.—Soluble in hydrochloric acid, **forming a stiff jelly upon evaporation,** page 271.

Section i.—B. B., in the closed tube give water, page 271.

Section ii.—B. B., in the closed tube, give none, or only traces of water, page 272.

Division 4.—Soluble in hydrochloric acid, **the silica separating in a pulverulent form without forming a perfect jelly,** page 275.

Section i.—B. B., in the closed tube give water, page 275.

Section ii.—B. B., in the closed tube yield no water or only a trace, page 278.

Division 5.—Are **insoluble** in, or **only slightly attacked** by, hydrochloric acid, page 279.

Class III.—Infusible, or fusible above 5.

Division 1.—B. B., after previous ignition, assume a fine blue color when moistened with cobalt solution and again ignited (**alumina**), page 289.

Section i.—B. B., in the closed tube yield much water, page 289.

Section ii.—B. B., in the closed tube yield little or no water, page 292.

Division 2.—Moistened with cobalt solution and ignited, assume a green color (**zinc**), page 295.

Division 3.—After ignition, B. B. have an **alkaline reaction,** and change the color of moistened turmeric paper to reddish-brown, or red litmus paper to blue. page 296.

Division 4.—**Completely soluble in hydrochloric acid,** or when this has no effect, in nitric acid, **without gelatinizing** on evaporation, or leaving a considerable residue of silica, page 299.

Division 5.—**Gelatinize** with hydrochloric acid, or are decomposed with **separation of silica,** page 303.

Section i.—B. B., in the closed tube yield water, page 303.

Section ii.—B. B., in the closed tube yield no water or but traces, page 306.

Division 6.—**Insoluble in hydrochloric acid,** or but very slightly attacked, page 307.

Section i.—Hardness under 4.5, can be scratched by a wire nail, page 307.

Section ii.—Hardness above 4.5 but not above 7, not scratched by a wire nail but can be scratched by quartz, page 308.

Section iii.—Hardness 7 or above, not scratched by quartz or only very faintly, page 312.

Group I.—MINERALS WITH METALLIC LUSTER.

Of the minerals which show an imperfect metallic luster, only such are included in this division as are also opaque, such as wolframite (tungstate of iron), chrome iron ore, etc. The following are ductile and *malleable*, and are easily distinguished from others by their physical properties:

Class I.—Native Malleable Metals and Mercury.

a. Color, white.

Native Mercury, Hg; is easily recognized, since it is fluid at common temperature; color, tin-white. G. 13.5–13.6.

Native Silver, Ag. Color, silver-white; is easily soluble in diluted nitric acid; and the solution even when much diluted gives with *hydrochloric acid a white curdy precipitate* of chloride of silver, which, exposed to the light, changes color, becoming bluish-gray. This precipitate is easily soluble in ammonia, from which copper foil precipitates the metal in the form of spongy silver, assuming its natural white color and luster when rubbed in an agate mortar. H. 2.5–3. G. 10–11. Moistened with sulphide of ammonium, bright silver at once becomes yellowish-brown to gray. (Compare *Amalgam* and *Electrum.*)

b. Color, yellow or red.

Native Gold, Au, and Electrum (gold alloyed with silver, Ag + x Au, more or less of a gold-yellow color). Native gold is *soluble only in nitro-hydrochloric acid (aqua regia), without perceptible residue.* The alloy with silver

is partly or entirely decomposed by nitro-hydrochloric acid *with the formation of chloride of silver*, which remains undissolved. If we dilute a few drops of the gold solution, concentrated by evaporation, with much water until the yellow color has almost disappeared, and then heat this liquid in a porcelain dish, together with tin-foil, a beautiful purple color is produced, yielding, when left standing, a purple-red deposit the so-called "*purple of Cassius.*" Heated to boiling with some crystals of oxalic acid, the metallic gold is precipitated as a brown powder, which by rubbing assumes metallic luster. The solution of chloride of gold gives with proto-sulphate of iron (*copperas*) the same reddish-brown precipitate of gold, which, by rubbing, assumes the color and metallic luster of gold. H. 2.5–3. G. 15.6–19.5.

NATIVE COPPER, Cu, is of a copper-red color; dissolves in nitric acid, forming a sky-blue solution which yields with ammonium hydrate a pale blue precipitate, soluble in excess to a deep azure-blue liquid. H. 2.75. G. 8.5–8.9.

c. Color, gray.

NATIVE LEAD, Pb. Of a lead-gray color; B. B. easily fused, fuming and coating the coal with a yellow oxide, red when hot. Dissolves easily in diluted nitric acid, and the solution gives, with hydrochloric acid, if much diluted, no precipitate,* but, on the addition of sulphuric acid, a heavy white precipitate of sulphate of lead. H. 1.5. G. 11.3.

* In a concentrated solution a white precipitate of chloride of lead is formed, soluble in much water or on boiling.

NATIVE PLATINUM, Pt, (H. 4.5–5. G. 17–18), and PALLADIUM, Pd. Both are infusible. Platinum is of a steel-gray color, soluble in nitro-hydrochloric acid, but not in nitric. Palladium is between a steel-gray and silver-white; soluble in nitric, but more easily in nitro-hydrochloric acid. The solution of platinum gives with carbonate of potassium a yellow precipitate, insoluble in excess. That of palladium gives a brownish precipitate soluble in excess of the reagent. H. 4.5–6. G. 11.8–12.2.

NATIVE IRON, Fe; color steel-gray; attracted by the magnet; infusible; soluble in hydrochloric acid; the solution gives reactions for iron. H. 4.5. G. 7–7.8.

Argentite (sulphuret of silver), is malleable, see below. (Compare also, *Hessite.*)

Class II.—Fusibility from 1–5, or easily volatilized.

Division I.—B. B. on charcoal evolve the strong garlic odor of arsenic and give white crystals of As_2O_3 in open tube.

a. Volatilizes without fusing.

NATIVE ARSENIC, As; volatilizes B. B. without fusing, and sublimes in a closed tube as a grayish-white crystalline coating. In some varieties the last portion fuses before volatilizing. Streak and fracture, tin-white. H. 3.5. G. 5.7–5.8.

b. On charcoal with S + KI gives a *lead* iodide coating.

Here belong the following rare minerals, viz.:

Sartorite, $PbAs_2S_4$ IV.
Dufrenoysite, $Pb_2AS_2S_5$ IV.
Jordanite, $Pb_4AS_2S_7$ V.

c. The roasted mineral shows *copper* in the borax bead, R. F.

Pearcite $(Ag,Cu)_9AsS_6$, V. *Contains silver*, the nitric acid solution gives a precipitate of white, curdy, AgCl. Color, iron black. With soda on charcoal reacts for *sulphur* on silver.

Enargite, $CuAsS_4$, IV. Contains *sulphur*, gives the sulphur reaction with soda. *Easily cleavable.* Color, iron black. *Binnite*, $Cu_6As_4S_9$ I, gives similar reactions. Rare.

TENNANTITE $(Cu_2, Fe, Zn,)_4As_2S_7$, I, gives *sulphur* reaction with soda. The nitric acid solution gives a precipitate for *iron* with ammonium hydrate in excess. Color, dark gray. Compare also *Tetrahedrite*. *Epigenite*, $Fe_3(Cu_2)_4As_2S_{12}$, IV, gives similar reactions. Rare.

The following rare copper arsenides contain *no sulphur*:

Domeykite, Cu_3As. Color, gray; tarnishing yellow, then dull brown.

Algodonite, Cu_6As. Color, gray; tarnishing as above.

Whitneyite, Cu_9As. Color, white; tarnishing as above.

d. The roasted mineral gives with borax the sapphire-blue bead of *cobalt*, but does not reduce to gray nickel in R. F.

SMALTITE, $CoAs_2$, I, gives a *sublimate of metallic arsenic* in a closed tube. Generally contains Ni and Fe. Contains little or *no sulphur*, not giving SO_2 in open tube. Color, tin white to steel gray, hard. Crystallizes in cubes and octahedrons. The orthorhombic form of the same composition, *Safflorite*, is generally fibrous and gives the same reactions. More rare, but also giving the same reactions, is *Skutterudite*, $CoAs_3$, I, tin white.

COBALTITE, CoAsS, I. Contains *sulphur*, and gives the sulphur reaction in the open tube. In the closed tube *gives no metallic arsenic*, except on strong ignition

a slight sublimate. Color, *tin white with a reddish or violet tinge.* Cleavage cubic.

GLAUCODOT, (Co,Fe)AsS, IV. Contains *sulphur* and reacts in open and closed tube as the last. Color, light steel gray to white. Cleavage, basal. In the nitric acid solution ammonia gives a precipitate of ferric hydrate.

e. The roasted mineral gives with borax the nickel bead, purplish when hot, brown when cold in O. F., and brown opaque or *gray with reduced nickel*, *R. F.* Sometimes cobalt shows in the bead, especially in O. F.

CHLOANTHITE, $NiAs_2$, I, gives readily a *sublimate of metallic arsenic* in the closed tube. *No sulphur* in open tube. Resembles smaltite. Here also belongs *Rammelsbergite*, NiS_2, IV, tin white, usually massive.

NICCOLITE, NiAs, III. *Pale coppery red. No sulphur* in the open tube. On strong ignition *a slight sublimate of metallic arsenic* in the closed tube.

GERSDORFFITE, NiAsS, I. *Tin white, cubic cleavage.* In the open tube gives *sulphur* reaction. On strong ignition *a slight sublimate of metallic arsenic.*

Compare also *Ullmannite*, which may contain some arsenic.

f. The roasted mineral gives with borax an *iron* reaction, or the mineral ignited for a long time on charcoal becomes *magnetic.*

ARSENOPYRITE, FeAsS, IV. In the closed tube *a sublimate of metallic arsenic;* in the open tube a *sulphur* reaction. Color, silver white. Prismatic or massive.

LEUCOPYRITE, Fe_3As_4, massive, and LÖLLINGITE, $FeAs_2$, IV. In the open tube *no sulphur* reaction. In the closed tube, *metallic arsenic* as with Arsenopyrite.

g. The roasted mineral becomes a spongy mass of gray platinum, *not soluble in any* simple acid.

Sperrylite, $PtAs_2$. A rare mineral.

Division 2.—B. B. on charcoal, or in the open glass tube, evolve the strong horseradish odor of selenium; the reducing flame is tinged blue.

All of the minerals in this division are of rare occurrence. They are selenides of lead, mercury, copper and silver. The following are the principal species: Tiemannite, HgSe; Zorgite, $(Pb,Cu_2)Se$; Naumannite, $(Ag_2Pb)Se$; Aguilarite, $Ag_2(S,Se)$; Clausthalite, PbSe.

Division 3.—B. B. on charcoal yield a whitish deposit, which colors the reducing flame greenish or greenish-blue. Impart to concentrated sulphuric acid, when gently heated with it in a test-tube, a purple-red or hyacinthine color, which, upon the addition of water disappears, while a blackish-gray precipitate forms (tellurium).

This precipitate, collected and dried upon a filter, imparts to concentrated sulphuric acid, when heat is first applied, a purple color, which again disappears upon continued heating. B. B. many compounds of tellurium evolve on charcoal the horseradish odor of selenium, caused by an accidental trace of this element. Heated in the open glass tube the sublimate of TeO_2 at first forms as a powder, but on continued heating melts to clear drops.

The minerals in this division are mostly of rare occurrence, but several of them are of much technical importance as gold or silver ores.

a. B. B. on charcoal completely volatile.

Tellurium, Te, III. Tin white with gray streak.

b. Heated with S + KI on charcoal gives a scarlet coating of *bismuth* iodide.

Tetradymite, Bi_2Te_2S, III. Generally reacts for sulphur in the open tube. Strong basal cleavage; color, tin white.

a. After long heating O. F. on charcoal, a metallic globule of *silver* or *gold* is obtained.

NAGYAGITE, $Pb_{10}Au_2Sb_2Te_6S_{15}$, IV, gives a yellow to green *lead iodide* coating when heated on charcoal with S + KI. After long heating a globule of *gold* remains. Scaly, with basal cleavage; color, dark gray.

SYLVANITE, $(Au,Ag)Te_2$, V. After long heating on charcoal a globule of *gold* or *gold and silver* alloy is obtained. Cleavable, *very brittle;* color, silver white. Here also belong *Krennerite*, $AuTe_2$, IV, CALAVERITE, $AuTe_2$, V, but usually massive, all silver white to pale brass yellow in color; also PETZITE, $(AuAg)_2Te$, I, massive, which is somewhat sectile and iron black in color. These are the "*telluride gold ores.*"

HESSITE, Ag_2Te, I. Yields on long heating on charcoal a globule of *silver*, which may show gold when dissolved in HNO_3. Color, dark gray. A silver ore.

Division 4.—B. B. on charcoal evolve copious fumes of antimony oxide, which deposits near the assay, and is driven off again when the charcoal is heated to redness. In the open tube a dense white coating of Sb_2O_3 forms, which does not melt to drops on further heating.

a. Gives, when heated on charcoal with S + KI, *only an antimony coating;* the mineral is completely volatile on continued heating.

ANTIMONY, Sb, III. When heated to redness continues to oxidize, and if the button is dropped when red hot it burns leaving *a white trail.* In the open tube the mineral gives *no sulphur* reaction.

STIBNITE, Sb_2S_3, IV, gives a *sulphur* reaction in the open tube. The powder treated with caustic potash becomes ochre yellow, and is partly dissolved.

b. Heated on charcoal with S + KI gives a parrot-green coating of *iodide of lead.* Mostly volatile on prolonged ignition.

JAMESONITE, $Pb_2Sb_2S_5$, IV, gives reactions for *lead, antimony* and *sulphur* only. When moistened with HCl does not color the flame blue (contains no copper). Generally fibrous; color dark gray. There are a number of rare sulphantimonides of lead that would belong here, of which the most important is *Boulangerite,* $Pb_5Sb_4S_{11}$, IV.

BOURNONITE, $Cu_2Pb_2Sb_2S_6$, IV. The residue after long heating gives a *copper* reaction in the borax bead, or the mineral moistened with a drop of HCl colors the flame blue (copper). Gives the sulphur reaction in the open tube.

Freieslebenite $(Pb,Ag_2)_5Sb_4S_{11}$, V. After long heating on charcoal a silver globule is obtained, which may be tested by dissolving in HNO_3 and precipitating by HCl. Color steel gray. *Diaphorite* has the same composition but is IV. *Brogniartite* is a silver-bearing Jamesonite.

c. Do not contain lead, but after decomposition with HNO_3 and settling, HCl gives in the clear solution a precipitate of *silver* chloride.

DYSCRASITE, Ag_3Sb, IV, gives *no sulphur* reaction in open tube. Color, silver white, brittle. Streak, white to gray. Tarnishes black. Fus. 1.5. A silver ore.

TETRAHEDRITE, *var.* FREIBERGITE $(Cu_2,Ag_2,Fe,Zn)_4Sb_2S_7$, I, gives a *sulphur* reaction in the open tube; an excess of ammonium hydrate in the clear HNO_3 solution produces a deep blue color, indicating *copper.* An important ore of silver. Fus. 1.5.

STEPHANITE, $Ag_{10}Sb_2S_8$, IV, gives the *sulphur* reaction in the open tube, but contains *no copper.* In six-sided

prisms or massive. Color, iron black; streak, black. Giving the same reactions we have *Polybasite*, Ag_9SbS_6, V, sometimes containing a little copper, color and streak same as stephanite. Here also would belong PYRARGYRITE, Ag_3SbS_3, III, when it is opaque. Color, dark gray or reddish, streak, dark red. Fusibility of the above = 1.

d. The nitric acid solution shows *copper* with excess of ammonia, but the mineral does not contain lead or silver.

TETRAHEDRITE $(Cu_2)_4Sb_2S_7$, I, generally contains Fe and Zn; also often Hg. Color, dark gray to iron black. Fusibility, 1.5. When in crystals usually in tetrahedrons.

e. Contains no copper, silver nor lead, but fuses to a magnetic globule indicating *iron*.

Berthierite, $FeSb_2S_4$, IV. Fibrous, color, steel gray. Fusibility, 2. Rare.

f. The roasted mineral gives a brown *nickel* bead with borax, and does not contain Cu, Fe, Pb, or Ag.

Ullmannite, NiSbS, I. Strong *cubic cleavage*, color, pale steel gray, streak, black. Fus. = 1.5.

Breithauptite, NiSb, III. Color, pale reddish white with a violet tinge. Gives no sulphur reaction in open tube. Fus. = 2.

Division 5.—Heated in the open glass tube give SO_2, which reddens and finally bleaches a strip of moistened blue litmus paper placed in the end. B. B. with soda give hepar which blackens silver when crushed upon it and moistened. Do not give the reactions of the preceding divisions.

a. With soda on charcoal O. F. gives globules of *lead* and a lead coating. With S + KI a yellow to parrot-green coating of lead iodide, but does not react for bismuth.

GALENITE, PbS, I. Reacts for lead and sulphur only.

Galenite often contains silver, and this may be detected by cupellation. Fusibility, 2. Strong, *cubical cleavage.* Color, lead gray.

b. With soda on charcoal O. F. gives globules of *silver*, recognized by dissolving them in HNO_3 and precipitating with HCl.

ARGENTITE, Ag_2S, I. Reacts for silver and sulphur only. *Malleable and sectile;* fusibility, 1.5; color, iron black; hardness, 2. *Acanthite* has the same composition, but is prismatic and apparently orthorhombic. Also sometimes giving silver beads as above are *Sternbergite*, $AgFe_2S_3$ IV, rare, and *Stromeyerite* $(CuAg)_2S$ IV, which is essentially Chalcocite containing silver. Compare Stromeyerite below.

c. With S + KI on charcoal a scarlet coating of *bismuth* iodide.

Bismuthinite, Bi_2S_3, IV. Reacts only for sulphur and bismuth. Color, lead gray; generally fibrous. Fusibility, 1. Here belong a number of rare sulphobismuthites of lead, copper, etc.

d. The roasted mineral gives a *copper* reaction in the borax bead, R. F. (copper red); when dissolved in HNO_3, ammonia in excess gives a blue color. Nearly all of these minerals give a precipitate of $Fe(OH)_3$ when treated with ammonia; the color of the mineral is an important distinguishing character.

CHALCOCITE, Cu_2S, IV. Contains little iron, but generally shows a trace. Color, steel gray; tarnishing steel blue, then black. Brittle. Gives no sulphur in closed tube. Fus. 2.5. Chalcocite sometimes contains a little silver and graduates into the next.

Stromeyerite $(CuAg)_2S$, IV. Somewhat sectile. Gives with HCl in the HNO_3 solution a precipitate of *silver chloride*, otherwise closely resembles Chalcocite. Fusibility, 2.

Covellite, CuS, III. Contains no iron. Color, *steel blue;* streak black, generally in plates or massive. Rare. Fus. 2.5. Gives sulphur in closed tube.

CHALCOPYRITE, $CuFeS_2$, II. Color, *brass yellow;* contains *iron.* Tarnishes to greens and purples, finally dull black. Fus. 2. The streak is greenish-blue. A common copper ore, "copper pyrites." Closely allied is the rare *Cubanite*, $CuFe_2S_4$, somewhat lighter brass yellow in color, but hardly distinguishable without a quantitative analysis.

BORNITE, Cu_3FeS_3, I. Color *bronze brown*, tarnishing *purple, blue, blue green;* contains *iron;* also sometimes a little silver. Fus. 2. A common copper ore, called "peacock copper," "variegated copper ore," "horse-flesh ore," etc. Generally massive.

STANNITE, Cu_2FeSnS_4, I. Contains *iron.* Heated alone on charcoal, a tin coating forms near the assay, recognized by ignition with cobalt nitrate. Color, tin white, or often bronzy from admixture of chalcopyrite. Fus. 1.5. Commonly massive. Tin pyrites.

c. The roasted mineral gives a *nickel* reaction in the borax bead, R. F. (brown or gray and opaque).

MILLERITE, NiS, III. Color pale brass yellow, in needles or fibrous; tarnish, dull greenish gray. Reacts for nickel and sulphur only. Fus. 2. A nickel ore.

PENTLANDITE (Ni,Fe)S, I. Color yellow bronze, massive. Contains iron; the nitric acid solution gives with ammonia a precipitate of ferric hydrate. Not magnetic before heating. Fus. 2. Compare *Linnaeite* below.

f. The roasted mineral gives a cobalt reaction with borax in O. F. (*sapphire-blue* bead).

Linnœite $(Co,Ni)_3S_4$, I, generally shows *nickel* when the borax bead is strongly reduced; or better after all of the cobalt has been oxidized from a fused bead of the original mineral, on charcoal with borax glass. Color, white with a pinkish tinge. In octahedrons and massive. Fus. 2. Here also belongs the rare *Carrollite*, $CuCo_2S_4$ I, steel gray.

g. The roasted mineral gives a *manganese* reaction in the borax bead, O. F. (amethyst-red).

Alabandite, MnS, I. Color brownish black, *streak, dark green*, cleavage, cubic. Soluble in a mixture of hot phosphoric and hydrochloric acids to a violet solution. Gives no sulphur in closed tube, or but a trace. This distinguishes Alabandite from *Hauerite*, MnS_2 I, which gives much sulphur in the closed tube. Fusibility of both, 3.

h. The roasted mineral gives an *iron* reaction in the borax bead O. F. (red brown when hot, yellow to colorless when cold). Note that the copper iron sulphides above are excluded by giving copper R. F.

PYRRHOTITE, FeS, III. *Magnetic before heating.* Gives little or no sulphur in closed tube. Color, bronze-brown; streak, black. Fus. 3. Soluble in HCl with evolution of H_2S. Generally contains a little Ni, which makes it valuable as an ore. The Ni is detected by qualitative separation; for example, the sulphides precipitated from a solution of the mineral by alkali sulphide are filtered and then washed with dilute HCl, when the residue may be roasted and tested for Ni in the bead.

PYRITE, FeS_2 (or Fe_6S_{10}), I. Pale brass yellow in *color, streak,* brownish black. Not magnetic befor

heating. In closed tube gives *much sulphur. Not attacked to any extent by boiling HCl.* When in nature oxidizes to limonite. In a strong (nearly saturated) solution of potassium chlorate at boiling temperature, the fine powder is slowly attacked, the solution after a time becoming turbid, and a dark reddish brown precipitate forming. Fragments of the mineral treated in the same way are scarcely attacked. In a diluted HNO_3 solution ($1HNO_3 + 5H_2O$) on heating the fine powder *dissolves completely, leaving no residue of sulphur* (modified from Penfield).

MARCASITE, FeS_2 (or Fe_2S_4), IV. Pale greenish brass yellow, paler than pyrite. Streak, grayish and somewhat greenish black. Not magnetic before heating. Gives sulphur in closed tube, *not attacked to any extent by boiling HCl.* Oxidizes much more readily than pyrite, and in nature forms ferrous sulphate to a large extent. In fine powder, treated with strong solution of $KClO_3$ at boiling temperature, marcasite is instantly attacked, the solution becomes ochre colored and turbid, and a pale yellow-brown precipitate falls, much more bulky than in the case of pyrite. Fragments similarly treated, at once become coated with a yellow brown precipitate. With nitric acid as given under pyrite the mineral *cakes and dissolves leaving a pellicle of sulphur.*

Many other oxidants distinguish between pyrite and marcasite, hydrogen peroxide on standing giving off gas bubbles rapidly in case of marcasite, very slowly in case of pyrite, and with pyrite a whitish flocculent precipitate forms on standing. They are important as sources of sulphur, being used in the manufacture of sulphuric acid. Both may carry gold.

Division 6.—Not belonging to the preceding divisions.

a. Give an *iron* reaction, B. B., in the borax bead.

HEMATITE, Fe_2O_3, III R. Color, steel gray, black, red when earthy. *Streak, red.* Usually not magnetic before heating, R. F. Fusibility 5 or over. The most important iron ore.

MAGNETITE, $FeFe_2O_4$, I. Color, iron black, streak, dead black. *Strongly magnetic* without heating, R. F. Fusibility 5. An important iron ore and rock-forming mineral.

Fayalite, Fe_2SiO_4, IV, and HORTONOLITE, $FeMgSiO_4$, IV, are usually attracted by a magnet without heating R. F. Gelatinize with HCl. Color, black, streak, brownish. These rock-making minerals show a greasy luster, and generally a columnar fracture. Fusibility 3–4.

ALLANITE, $Ca_2(AlOH)(Al,Ce,Fe)_2(SiO_4)_3$, V. Color, pitchy-black; streak, greenish to brownish gray. Fuses readily with *strong intumescence*, B. B. Gelatinizes with HCl. Gives reactions for Ce, etc. A rock-forming mineral in some granites and some feldspathic rocks.

Ilvaite, $CaFe_2(FeOH)(SiO_4)_2$, IV. Color and streak, black. Fuses readily with *slight or no, intumescence*, B. B. Gelatinizes with HCl. Not common.

Samarskite, $(Fe,Ca,UO_2)_3(Ce,Y)_2(NbO_3)_2$, IV. Color, black, streak, dark red-brown. The very fine powder boiled with HCl and tin colors the solution *azure blue.* Reacts for uranium and the Cerium group of metals. Rare.

Compare also *Columbite*, sometimes fusible.

b. Give a *manganese* reaction, B. B., in the borax bead.

WOLFRAMITE $(FeMn)WO_4$, V. Color, black or brownish black, streak, reddish brown to dark brown. When

the very fine powder is boiled with aqua regia, the test tube becomes coated with yellow WO_3. If now the aqua regia is poured off and HCl with tin added, the solution immediately assumes a *sapphire blue color.* This is the principal tungsten ore, used for ferro-tungsten, etc. HÜBNERITE is similar, but generally non-metallic.

c. Gives a *copper* reaction, B. B., in the borax bead.

TENORITE or MELACONITE, CuO. Massive. Color and streak, black. Compare also *Cuprite*, Cu_2O, which sometimes looks submetallic to metallic. Ores of copper.

d. Not included in the above sections.

BISMUTH, Bi, III. Tin white with a *reddish tinge.* With S + KI the scarlet coating of bismuth iodide. Rare.

AMALGAM (Ag,Hg). Color, silver white, streak, shining, gray. Gives *metallic mercury* in the closed tube, leaving spongy silver. Rare.

Class III.—**Infusible or fusibility above 5, and non-volatile.**

Division 1.—B. B. gives in the borax bead a manganese reaction (amethyst-red, O. F.).

PYROLUSITE, MnO_2 (with small percentage of water), IV. Color, iron black, streak, dead black. Gives but little water in a closed tube. Fracture, generally fibrous, or may be compact. *Soft.*

Braunite, Mn_2O_3, II, and Hausmannite, Mn_3O_4, II, are anhydrous; color, black and streak, dark brown (see Physical Tables, Part III). Braunite generally con*tains some* SiO_2.

Manganite, MnO.OH, IV. Color iron black, streak dark brown. Gives much water in a closed tube. Pyrolusite is often pseudomorphous after Manganite. Generally in crystals or fibrous.

PSILOMELANE. A manganese and barium manganite of uncertain composition; in botryoidal masses, not crystalline. Gives water in closed tube. Generally gives a barium flame, B. B. Streak, black. *Hard.*

Psilomelane and pyrolusite are important manganese ores.

Here also belongs *Chalcophanite* $(Zn, Mn)Mn_2O_5.2H_2O$, III R, which gives water in the closed tube and a coating of ZnO on careful and intense heating on charcoal, B. B.

Compare *Franklinite* and *Columbite* below, which may give reactions for manganese or iron B. B. with borax.

Division 2.—Are magnetic or when heated on charcoal in R. F. become so; and give an iron reaction in the borax bead.

a. Magnetic before heating.

MAGNETITE, $FeFe_2O_4$, I. Color, iron black, streak, dead black. Sometimes slightly fusible. Soluble in HCl with difficulty, *reacts for ferrous and ferric iron.* May contain titanium in small amount. Magnetite is an important iron ore when free from titanium.

ILMENITE, $FeTiO_3 + Fe_2O_3$, III R. Color, iron black, streak, brownish black. The very fine powder dissolved in HCl and boiled with tin gives a *violet* color to the solution. Most specimens of ilmenite are magnetic, perhaps only slightly, before heating R. F. Titanic *iron ore or menaccanite* (*ilmenite*) is not used for iron making; *it is a rock-making mineral.*

Compare also *Hematite*, *Franklinite* and *Chromite* which may be somewhat magnetic before heating.

b. Give *water* in the closed tube.

LIMONITE, $Fe_4O_3(OH)_6$, IV, not in crystals. Color dark brown to black, *streak yellow brown;* compact to fibrous fracture. An important iron ore ("brown hematite").

GOETHITE, FeO.OH, IV. Dark brown to black, *streak ocher yellow.* Fracture generally fibrous. Distinguished from limonite by its streak, and by occurring in crystals. An iron ore.

TURGITE, $Fe_4O_5(OH)_2$, massive. Color black, *streak red*, like hematite. *Decrepitates* strongly when heated in a closed tube, gives less water than the above. An iron ore.

c. Give *no water* in the closed tube.

HEMATITE, Fe_2O_3, III R. Color, steel gray to black, *streak, red. Does not decrepitate* in closed tube. The most important ore of iron. Sometimes slightly magnetic.

FRANKLINITE $(Zn, Mn, Fe)Fe_2O_4$, I. Color, iron black, *streak, reddish or brownish black.* Gives a *manganese reaction* with soda on platinum wire, bluish-green opaque bead. On charcoal with soda on strong heating a zinc coating recognized by $Co(NO_3)_2$. Varieties high in Mn are liable to be quite magnetic before heating.

Some varieties of *Sphalerite* containing iron, and *Siderite*, $FeCO_3$, have a sub-metallic luster, see under non-metallic luster. Compare also *Chromite* and *Columbite*, below, which may become magnetic in R. F.]

Some varieties of *rutile* and *brookite* contain enough iron to look submetallic and become magnetic in R. F.

Division 3.—Not included in the preceding divisions.

a. **Soft, marking paper.**

GRAPHITE, C, III. Iron-black color and streak, generally scaly or with micaceous cleavage. B. B. unchanged or only very slowly consumed. Heated with $NaNO_3$ or KNO_3 the mineral *puffs up* or exfoliates. Used for pencils, as a lubricant, for crucibles, etc.

MOLYBDENITE, MoS_2, III. Color, bluish lead gray, streak, gray, slightly greenish; strong micaceous cleavage. B. B. becomes coated with lemon yellow MoO_3, which reacts with borax or salt of phosphorus for molybdenum. Heated with a nitrate, molybdenite *deflagrates*. HNO_3 converts it to MoO_3, lemon yellow. If a little of this MoO_3 be heated with a drop of concentrated H_2SO_4 and a minute fragment of some organic matter, as paper, in a porcelain dish, a beautiful blue color is obtained.

b. **Gives an emerald-green bead with borax or salt of phosphorus, indicating *chromium*.**

CHROMITE, $FeCr_2O_4$, I. Color, black to brownish black, *streak, brownish to olive green.* Some varieties are quite magnetic before heating; all become so when the fine powder is strongly heated with soda on charcoal. Some varieties contain magnesium and aluminium. Chrome iron ore.

c. **Gives in the salt of phosphorus bead a reaction for *uranium*, yellow green O. F. and green R. F.**

URANINITE. Composition uncertain. Contains UO_2, UO_3, Th, Pb, Ra, He and Ar. Pitchy black in color with a dark brown streak. Dilute H_2SO_4 dissolves it with

evolution of a gas consisting of nitrogen, argon, helium, etc. Ammonia gives a *sulphur yellow* precipitate in the HNO_3 solution. This is the principal uranium ore.

c. The very fine powder boiled with HCl and then tin added gives a *violet* or *blue* solution. In many cases it is better to fuse with borax and dissolve the fusion with HCl.

COLUMBITE $(Fe.Mn)[(Nb,Ta)O_3]_2$, IV. Color, black, often with a *steel blue tarnish;* streak, reddish-brown or reddish-black. Gives an *azure blue color* when treated with HCl and tin as above. With soda on the wire a blue-green manganese reaction. With soda on charcoal generally becomes magnetic. Rare.

Perovskite, $CaTiO_3$, I. Color, black, streak, gray. Occurs in cubes, octahedrons, etc. Treated as above with HCl and tin it gives a *violet solution.* The Ca may be detected by fusing with soda, taking up in HCl, precipitating the TiO_2 with ammonia, and then the Ca as oxalate. Closely allied is *Dysanalyte* which contains Fe, Nb, Y, Ce, etc., in addition to Ca and Ti; but crystallizes in cubes, octahedra, etc., like Perovskite. When Dysanalyte is treated with HCl and tin as above, the solution *at first becomes violet, but on long boiling changes to blue.* Both of these minerals are rare.

Brookite, *Rutile* and *Octahedrite* may have metallic luster when high in iron, and would then come into this group. See under non-metallic luster.

CASSITERITE, SnO_2, II, sometimes has a submetallic luster and is opaque. On charcoal with soda and charcoal dust *globules of tin* and a tin coating would be obtained. See under non-metallic luster.

GROUP II.—MINERALS WITHOUT METALLIC LUSTER.

Class I.—Volatilize Easily or are Combustible.

Many minerals (which are not volatile) decrepitate and fly apart when heated; such may be heated in a closed glass tube, when they will not volatilize and form a sublimate as *volatile* substances do.

a. On charcoal give the garlic odor of *arsenic* and an arsenic coating, white, depositing far from the assay.

Arsenolite, As_2O_3, I. In the closed tube sublimes to crystalline As_2O_3, white; but does not give a colored sublimate. Colorless or white. Occurs with arsenides and arsenic sulphides.

Claudetite has the same composition, but is monoclinic in crystallization.

Orpiment, As_2S_3, V. Color, yellow, micaceous or scaly. In the closed tube gives a reddish sublimate (when cold, darker when hot) and often also some As_2O_3. With soda on charcoal a sulphur reaction. Rather rare.

Realgar, As_2S_2, V. Color, aurora red, crystalline to massive, also earthy; luster, resinous to greasy. Reactions same as for Orpiment. Rare.

b. With soda on charcoal a *sulphur* reaction and odor of SO_2, but no garlic odor or arsenic coating.

SULPHUR, S, IV. Takes fire and burns in the air. Immediately blackens a piece of silver held in the flame. Heated in the open tube, the SO_2 reddens and then bleaches a moistened piece of litmus paper. Color, sulphur yellow; resinous. Associated with certain gypsum beds, and in volcanic districts.

Kermesite, Sb_2S_2O, V. Color, purple brown or maroon;

fibrous, often in radiating tufts. On charcoal gives a white antimony coating. Treated with caustic potash the powder changes to an orange yellow color.

CINNABAR, HgS, III R. Color, red, streak, vermilion; luster adamantine to sub-metallic adamantine; very heavy, G. = 8.1. In closed tube with dry soda a *gray* sublimate of metallic mercury. Cinnabar is the principal mercury ore.

c. On charcoal give a white *antimony* coating, but do not give an odor of As or S. In the closed tube volatilize after fusion and give a sublimate which is partly crystalline, octahedrons or prisms.

Senarmontite, Sb_2O_3, I. Colorless to grayish, luster, adamantine to resinous; often in octahedrons. With stibnite as an oxidation product. Rather rare.

Valentinite, Sb_2O_3, IV. Colorless to white, luster, pearly to silky, or adamantine. In fibrous tufts of crystals, cleavable. With senarmontite, rather rare.

d. Gives odor of *ammonia* when heated with caustic potash or soda in a test-tube.

SAL AMMONIAC, NH_4Cl, I. Taste, sharp and saline. Generally waxy, often fibrous. Reacts for chloride with CuO. With guano, etc.; not common. *Mascagnite*, $(NH_4)_2SO_4$, IV, reacts for sulphate. Rare.

Class II.—**Fuse easily between 1 and 5 inclusive, and volatilize only partially or not at all.**

Part A.—B. B. fused with soda on charcoal yield a metallic globule, or fused alone in the R. F. form a mass, which when cold, is attracted by a magnet.

Division 1.—B. B. yield with soda, or borax and soda, a silver globule, which is soluble in diluted HNO_3, and from which solution HCl throws down a curdy precipitate of AgCl, not soluble on boiling.

a. **The residue from the fusion on charcoal gives a *sulphur* reaction on silver coin.**

PROUSTITE, Ag_3AsS_3, III R, hemimorphic. Light ruby silver ore; generally red in color, *streak, bright red*; luster, sub-metallic adamantine. Gives odor of arsenic and arsenic coating on charcoal. In closed tube a sublimate of As_2S_3, red when hot, reddish orange when cold. A valuable silver ore.

PYRARGYRITE, Ag_3SbS_3, III R, hemimorphic. Dark ruby silver ore; color, dark red to nearly black, *streak, purplish-red;* lustre submetallic-adamantine. On charcoal an antimony coating; no sublimate of Sb_2S_3 in closed tube, except at very high temperature.

b. **The residue from the fusion on charcoal gives *no sulphur* reaction on silver coin.**

CERARGYRITE, AgCl, I. *Waxy and Soft. Color, pearl gray*, luster, glistening to sub-adamantine. In salt of phosphorus bead saturated with CuO a chlorine reaction (colors the flame blue). Cerargyrite or *Horn Silver* is an important silver ore.

EMBOLITE, Ag (Cl. Br), I. Olive green to *yellow-green*, luster glistening to resinous, *soft and waxy.* Contains chlorine as shown by salt of phosphorus bead saturated with CuO (colors flame blue), also contains bromine as shown by fusing in closed glass tube with bismuth sulphide, when a yellow sublimate forms. Galenite may also be used, the lead bromide formed being yellow when hot, white when cold. An important silver ore.

Division 2.—B. B. with soda yield a lead globule, and a lead *coating on the charcoal,* best recognized by using S + KI, *when the lead iodide* coating is parrot green to orange.

a. The mineral fused with soda on charcoal gives a *sulphur* reaction.

ANGLESITE, $PbSO_4$, IV. Colorless, sometimes grayish; luster, adamantine to resinous; heavy. *Reacts only for lead and sulphur.* A lead ore, occuring in the zone of oxidation, near the surface. Here belong also the rare compounds, *Linarite, Lanarkite, etc.*

b. The mineral after heating with soda and metallic magnesium in a closed tube, gives a *phosphorus* reaction.

PYROMORPHITE, $Pb_5Cl(PO_4)_3$, III, pyramidal. Colors, variable: Nearly colorless, green, yellow, brownish; luster, resinous to adamantine. The mineral *is not reduced alone on charcoal*, but fuses to a bead which shows crystal facets on cooling. A lead ore.

The rare *Vauquelinite*, phospho-chromate of lead, belongs here; it gives a chromium bead.

c. The mineral heated strongly with a little charcoal in a closed tube gives an *arsenic* mirror.

MIMETITE, $Pb_5Cl(AsO_4)_3$, III, pyramidal. Colors: Yellow, orange, brownish, nearly colorless; luster, resinous to adamantine. The mineral *reduces alone on charcoal*, O. F., evolves odor of arsenic and gives an arsenic coating.

d. The roasted mineral in the salt of phosphorus bead gives a *vanadium* reaction, deep yellow in O. F., green in R. F. All are rare minerals.

VANADINITE, $Pb_5Cl(VO_4)_3$, III, pyramidal. Red, brown, yellow; luster, adamantine to resinous. Gives a chlorine reaction in a salt of phosphorus bead saturated with CuO (blue flame). *Endlichite* is a mixture of *Mimetite* and Vanadinite.

DESCLOIZITE, $(Pb,Zn)(PbOH)VO_4$, IV. Brown, red;

sub-adamantine to resinous. Gives water in a closed tube. The coating on charcoal reacts for zinc with cobalt nitrate.

e. In the salt of phosphorus bead a green color.

CROCOITE, $PbCrO_4$, V. Color, aurora red, adamantine to resinous; streak, orange. In the borax bead in O. F. reddish when hot, yellow green on cooling; in R. F. dull green when hot, emerald green on cooling.

WULFENITE, $PbMoO_4$, II. Various shades of yellow, red; luster, adamantine. Heated with a few drops of H_2SO_4 in a porcelain dish, and a little alcohol added, the solution becomes a strong blue on cooling. The HCl solution reduced with tin becomes first apple green, then brownish olive and finally red. Compare *Stolzite*, $PbWO_4$, which reduces to a blue color with HCl and tin, and gives in the salt of phosphorus bead a sapphire blue color R. F.

f. Soluble in warm dilute HNO_3 with effervescence.

CERUSSITE, $PbCO_3$, IV. Colorless, yellowish; adamantine luster. Generally decrepitates. Reacts only for lead and CO_2. An important lead ore.

Division 3.—In the borax bead give a copper reaction in R. F.; moistened with HCl give a blue color to the flame.

a. Color green, give an *arsenical* odor when heated B. B. on charcoal, and generally give a brittle bead of copper arsenide.

Olivenite, $(CuOH)CuAsO_4$, IV. Color dark olive green. Fused carefully in the forceps crystallizes on cooling on the surface; gives little water in the closed tube. Rather rare.

Liroconite, $Al_4Cu_9(OH)_{15}(AsO_4)_5.20H_2O$, V. Color, *green, sky blue.* Heated gently does not decrepitate,

but becomes smalt blue. Soluble in ammonia with separation of a white flocculent precipitate. Gives much water in the closed tube.

b. Contains *chlorine* and gives a blue flame without moistening with HCl.

Atacamite, $Cu(OH)Cl.Cu(OH)_2$, IV. Deep green to emerald green; streak, apple green. Gives water in the closed tube. Local.

c. Contain *sulphur* and give a sulphur reaction with soda on charcoal.

Covellite, CuS, III. Steel blue color; scaly or in flat crystals. In open tube gives SO_2 fumes which redden and bleach moistened litmus paper. Rare.

CHALCANTHITE, *Blue Vitriol*, $CuSO_4.5H_2O$, VI. Color, blue; *soluble in water;* the solution deposits copper on a piece of iron or steel dipped into it; gives water in a closed tube. Results from the oxidation of sulphide ores of copper. *Brochantite*, $2Cu(OH)_2.(CuOH)_2SO_4$, belongs here, deep green, insoluble in water.

d. Evolve CO_2 with effervescence when dissolved in hydrochloric acid.

MALACHITE, $(CuOH)_2CO_3$, V. *Color, green, fibrous;* gives much water in a closed tube. Often in crusts and radiating tufts of fibers. A surface oxidation product of sulphide copper ores, and an important ore of copper.

AZURITE, $(CuOH)_2Cu(CO_3)_2$, V. *Color, deep blue;* not fibrous; gives much water in a closed tube. Occurs with Malachite and is an important ore of copper.

e. Dissolve quietly in HCl, do not evolve CO_2.

CUPRITE, Cu_2O, I. Color, cochineal red; streak, brick *red. The* cuprous condition of the copper may be de-

tected by diluting the concentrated HCl solution, when white cuprous chloride separates. Caustic potash gives an ocher yellow precipitate. An important copper ore.

TENORITE or MELACONITE, CuO. Earthy when non-metallic. *Color and streak, black.* The concentrated HCl solution is not precipitated by addition of water. Caustic potash gives in the HCl solution a pale blue precipitate. A copper ore, often found mixed with wad, malachite, etc.; the wad gives it a brownish color, and often a manganese reaction.

Libethenite, $(CuOH)CuPO_4$, IV, and *Torbernite*, $Cu(UO_2)_2(PO_4)_2.8H_2O$, II, belong here. Both give a phosphorus reaction with metallic magnesium and soda, the solution of torbernite gives with ammonia in excess a bluish green precipitate, with the deep blue solution of copper ammonium salt. This precipitate is not soluble in ammonia. Torbernite also gives a green bead with salt of phosphorus R. F. Libethenite is dark olive green, crystals pyramidal; torbernite is apple green, submetallic to pearly, in square tabular crystals.

Division 4.—B. B. give to the borax bead the sapphire blue color of cobalt.

ERYTHRITE, $Co_3(AsO_4)_2.8H_2O$, V. Prismatic. Color, rose to *peach-blossom red.* In the closed tube gives water and becomes blue. In HCl a rose-colored solution. Arsenic may be detected by heating with charcoal and Na_2CO_3 in a closed tube, when an arsenic mirror forms. Also called "Cobalt bloom."

Annabergite, $Ni_3(AsO_4)_2.8H_2O$, V. Earthy. *Color, apple green.* Generally gives a blue bead with borax, but in R. F. with strong saturation, gray reduced nickel

separates. Arsenic may be detected as with Erythrite. *Nickel bloom*, an oxidation product on nickel ores.

Division 5.—Fused B. B. in the forceps or on charcoal in the reducing flame for several minutes yield a mass that after cooling is attracted by a magnet, but give none of the reactions of the preceding divisions.

i. When heated on charcoal give the garlic odor of arsenic.

Scorodite, $FeAsO_4.2H_2O$, IV. Color greenish or brownish, crystals pyramidal. In a solution of caustic potash the powder becomes red brown. Closely allied is *Pharmacosiderite* $(FeOH)_3Fe(AsO_4)_3.6H_2O$, I, tetrahedral. Green, yellow, brownish; in cubes or tetrahedrons. It gives the same reactions as scorodite.

Compare Annabergite above, which occasionally gives a nickel bead with borax, when free from cobalt, but gives the odor of arsenic and may become magnetic in R. F.

ii. Soluble in hydrochloric acid without perceptible residue, and without forming a jelly upon evaporation.

a. Streak, strongly colored.

HEMATITE, Fe_2O_3, III R. *Streak, deep red* (Indian red). Fusible with difficulty, easily becoming magnetic, R. F.; gives no water in the closed tube. A very important iron ore.

LIMONITE, $Fe_4O_3(OH)_6$, IV. *Streak, yellow ocher* colored; structure fibrous to earthy. Fusible with difficulty, easily becoming magnetic R. F. Gives much water in the closed tube. "Brown hematite" a very important iron ore.

Goethite, $FeO(OH)$, IV, closely resembles limonite; the streak is somewhat lighter colored. An iron ore.

Turgite or *Hydrohematite* is generally found to be infusible; it *decrepitates* and yields water in a closed tube. Streak, red like hematite.

b. Give with soda on charcoal a *sulphur* reaction.

MELANTERITE, $FeSO_4.7H_2O$, V. Pale green, *soluble in water*, taste, sweetish astringent. Fuses with swelling to a magnetic slaggy mass. Gives water in the closed tube. Occurs in solution in many mine waters. Known also as *copperas* or *green vitriol.*

Coquimbite, $Fe_2(SO_4)_3.9H_2O$, III R. Color, whitish, amethyst, yellowish. Somewhat soluble in water, taste, astringent. Caustic potash changes the powder to brownish-red.

Jarosite, $K[Fe(OH)_2]_3(SO_4)_2$, III R., gives similar reactions to the last, but is scarcely soluble in water. Gives a potash flame B. B. Color, yellow to brownish. *Copiapite*, $Fe_2(FeOH)_2(SO_4)_5.18H_2O$, V, is yellow, with yellow powder, and same reactions as jarosite, but contains no potassium and does not give a potassium flame.

c. Dissolve with effervescence in warm HCl.

SIDERITE, $FeCO_3$, III R. Colors, brownish to ash gray. Cleavable parallel to the rhombohedron, in three directions at angles of 107°. *Reacts only for iron and carbon dioxide.* Compare also sphalerite, which is cleavable and effervesces with warm acid, but gives off H_2S.

d. Heated with Na_2CO_3 and metallic magnesium in a closed tube and the resulting mass placed in water, evolve phosphine, readily recognized by its characteristic disagreeable odor.

VIVIANITE, $Fe_3(PO_4)_2.8H_2O$, V. Color, blue, greenish; luster, pearly. The HCl solution reacts for ferrous *on with potassium* ferricyanide. Yields much wate

in a closed tube. A source of phosphoric acid in some phosphate deposits. Occurs with some limonite ores as an impurity.

Dufrenite, $Fe_2(OH)_3PO_4$, IV. Dull olive to blackish green; generally fibrous with a silky luster. Reacts for ferric iron in the HCl solution. Yields much water in a closed tube. An impurity in some limonite ores.

Cacoxenite is similar in composition, color, gold-yellow; silky luster. Found as an impurity in some limonite ores.

Triplite and *Triphyllite* are rare iron phosphates containing manganese. Both give manganese reactions in the beads.

iii. Gelatinize with hydrochloric acid or are decomposed with the separation of silica.

a. Gelatinize readily with hydrochloric acid.

FAYALITE, Fe_2SiO_4, IV. Color, dark yellowish green to nearly black. Sometimes magnetic before heating, due to admixed magnetite. The HCl solution reacts for ferrous iron only. Iron chrysolite, a rock-forming mineral.

Closely allied to Fayalite are *Hortonolite* $(Fe,Mg)_2SiO_4$, *Knebelite* $(Fe,Mn)_2SiO_4$ and *Roepperite* $(Fe,Mn,Mg,Zn)_2SiO_4$. The Mn may be detected in the Na_2CO_3 bead the other constituents best by wet separation.

Ilvaite, $CaFe_2(Fe.OH)(SiO_4)_2$, IV. Color, iron black; submetallic. Fuses quietly or with but *little intumescence* to a black magnetic bead. Reacts for both ferrous and ferric iron when dissolved in HCl. Not common.

ALLANITE, $Ca_2(Al.OH)(AlFeCe)_2(SiO_4)_3$, V. Color, *pitchy black*, streak, greenish or brownish gray. Fuses *with swelling or frothing* to a black glass. The cerium

group may be examined for as given under reactions for cerium, etc. The SiO_2 is rendered insoluble by evaporating the HCl solution to dryness, and then separated in the usual way, by taking up in HCl and water, and filtering. From this solution ammonia throws down a heavy precipitate, which is then treated with oxalic acid. The residue not soluble in oxalic acid is first ignited and then treated with dilute HCl to extract calcium; the ignition of the final residue gives a brick red color (cerium oxides). Allanite is a rock-making mineral in certain granites, syenites and gneisses.

Lepidomelane, $(K,H)_2(Fe,Mg)_2(Fe,Al)_2(SiO_4)_3$, V. Micaceous, black; streak, greenish-gray; nearly opaque. Gelatinizes with acid fairly well, or leaves a residue of flakes of silica. Easily recognized by its micaceous texture; generally an aggregation of scales.

b. Are decomposed with separation of silica, but *without gelatinizing.*

Compare *Allanite* and *Lepidomelane* above, which sometimes do not gelatinize perfectly.

Biotite, $(K,H)_2(MgFe)_2(Fe,Al)_2(SiO_4)_3$, V. Black mica, transparent in thin plates with green or brownish color. Attacked by HCl with separation of a residue of silica; sometimes only slightly attacked. An important rock-making mineral.

Astrophyllite, $(H,Na,K)_4(Fe,Mn)_4(Si,Ti,Zr)_5O_{16}$, IV, closely resembles a brownish biotite, but is generally in long bladed crystals of a bronzy yellow-brown color. Decomposed by HCl with separation of silica, and *when this solution is* boiled with tin it assumes a violet *color, indicating Titanium.* Rather rare.

ANDRADITE $Ca_3Fe_2(SiO_4)_3$, I. Calcium-iron garnet, readily recognized by its *isometric* form. Decomposed with separation of silica or may gelatinize imperfectly. Colors are various shades of brown, yellow and green, sometimes reddish. The solution reacts for ferric iron and calcium. Andradite is a rock-making mineral and sometimes a gangue mineral. Some varieties as Topazolite and Demantoid are valued as gems.

iv. Only slightly attacked by hydrochloric acid or insoluble in acids.

WOLFRAMITE, $(Fe,Mn)WO_4$, V. Color black, brown black; luster, submetallic. In the soda bead in O. F. gives the blue green of *manganese*. The fine powder boiled with aqua regia deposits a yellow powder upon the test-tube; if now the acid be poured off and HCl and tin added the liquid becomes *sky blue* (*tungsten*). *Hubnerite*, $MnWO_4$, resembles Wolframite but is bronzy colored and generally in long stalky crystals. Both are ores of tungsten and are used for making tungstic oxide and ferrotungsten.

ALMANDITE, $Fe_3Al_2(SiO_4)_3$, I. Generally deep red to brownish red, recognized by its *isometric* crystals. *After fusion gelatinizes* with hydrochloric acid. Very hard (7.5), fracture uneven. Red garnet of this composition is a common rock-making mineral in mica schists, gneisses and granites.

ACMITE, $NaFe(SiO_3)_2$, V. In striated prisms, greenish or brownish black; cleavage prismatic, with angle of 93°. Fuses *quietly* and readily, gives a sodium flame. A pyroxene found in nepheline (elaeolite) syenite.

ARFVEDSONITE, $4[(Ca, Na_2, Fe, Mg)SiO_3].(Ca,Mg,Fe)_2(Al,Fe)_2(AlO_3)_2(SiO_3)_2$, V. Cleavage parallel to the

prism, *cleavage angle 125°*. *Fuses with intumescence*, giving a sodium flame. Arfvedsonite is generally massive or in fair-sized crystals. Closely allied is *crocidolite*, which is bluish gray or lavender, fibrous, an asbestus. These amphiboles occur in granite-like rocks, rich in soda.

HYPERSTHENE $(FeMg)SiO_3$, IV. Bronze brown to nearly black, with a *bronzy schiller*. Generally massive, cleavable or almost fibrous. Fuses with difficulty.

BIOTITE $(H,K)_2(Mg,Fe)_2(Al,Fe)_2(SiO_4)_3$, V. Micaceous, black; by transmitted light in thin plates brownish or greenish. Fuses with difficulty. Some varieties of biotite become quite magnetic in the reducing flame.

Compare also those dark silicates that contain iron, as Pyroxene, Amphibole, Tourmaline, etc., also some containing manganese, as Rhodonite, which may become somewhat magnetic on heating R. F.

Part B.—Fused with sodium carbonate on charcoal yield no metallic globule, or fused alone in the reducing flame do not become magnetic.

Division 1.—After fusion and continued heating in the forceps or on platinum foil give an alkaline reaction and change the color of moistened tumeric paper to brown.

In making this test the ignited fragment, after cooling, is placed upon a piece of dry turmeric paper and a drop of water allowed to fall upon the mineral; when, after a minute, the mineral may be removed, and then, if it gives an alkaline reaction, a brown stain will be seen upon the paper.

Section i.—Easily and completely soluble in water.

a. Heated on charcoal in the reducing flame give a *sulphur* re-

action when placed upon silver and moistened, the silver becoming black by formation of sulphide.

THENARDITE, Na_2SO_4, IV. Colorless. Gives *no water* in closed tube. Heated on platinum wire a strong *sodium* flame. Taste, cooling, somewhat bitter. An "alkali" salt in salt lake deposits, on alkali plains, etc.

MIRABILITE, $Na_2SO_4.10H_2O$, V. Colorless. Very soluble and gives *much water* in closed tube. On platinum wire a strong *sodium* flame. Common in solution in mineral springs; and in the salts from evaporation of such springs, from the margins of salt lakes, etc.

EPSOMITE, EPSOM SALT, $MgSO_4.7H_2O$, IV. Colorless. Gives no flame coloration. In closed tube liquefies in its water of crystallization and gives much water, which is acid. After long heating on charcoal an infusible mass is obtained which, moistened with cobalt nitrate and again ignited, assumes a *pink* color, indicating *magnesium*. Taste very bitter. An efflorescence in many caves, mines, etc., and common, in solution, in mineral waters. *Kieserite*, $MgSO_2.H_2O$, V, gives similar reactions.

KALINITE, Potash Alum, $KAl(SO_4)_2.12H_2O$, I. B. B. first fuses and froths, then forms a spongy infusible mass, which, after moistening with cobalt nitrate and again igniting, assumes a *smalt blue* color indicating *aluminium*. Gives much water in closed tube. An efflorescence on slates, etc.

Hanksite, $9Na_2SO_4.2Na_2CO_3.KCl$, III. Colorless. B. B. on platinum wire a strong *sodium* flame. Effervesces with acid (CO_2). Gives the *chlorine* reaction (azure blue flame) in a bead of salt of phosphorus saturated *with CuO*. Found in salt lake deposits.

Kainite, $MgSO_4.KCl.3H_2O$, V. Colorless. B. B. on platinum wire a strong *potassium* flame. Reacts for *chlorine* in a salt of phosphorus bead saturated with CuO. The residue after long ignition gives a *magnesium reaction* (*pink*) with cobalt nitrate. In certain salt deposits.

b. Effervesce when treated with acids, but do not give a sulphur reaction; carbonates.

Natron, Soda, $Na_2CO_3.10H_2O$, V. Colorless. Melts in its water of crystallization in closed tube. Its solution is strongly alkaline. Gives an intense *sodium* flame. Generally occurs in solution in nature.

TRONA, $HNaCO_3.Na_2CO_3.2H_2O$, V. Colorless. Heated gently in closed tube gives water and CO_2, (coloring blue litmus paper red) but without melting in its water of crystallization. Gives an intense *sodium* flame; its solution is alkaline. Common in salt lake deposits, in alkali deposits, etc.; a source of soda. *Thermonatrite*, $Na_2CO_3.H_2O$, IV, is found with Trona. It does not give off CO_2 when heated gently in a closed tube.

c. Impart an azure-blue color to the flame in a bead of salt of phosphorus saturated with CuO (indicating *chlorine*), but do not give the reactions of the preceding divisions.

HALITE, common salt, NaCl, I. Colorless; taste, saline. Gives an intense *sodium* flame. Yields *no water* in closed tube, but generally *decrepitates*. Common in deposits as rock salt, in solution in brine springs, salt lakes, the sea, etc.

SYLVITE, KCl, I. Colorless. Taste, somewhat sharper than Halite, slightly bitter. Gives a strong *potassium* flame. Yields *no water* in a closed tube. Found principally in the Stassfurt salt deposit.

CARNALLITE, $MgCl_2.KCl.6H_2O$, IV. Colorless, reddish; granular massive. Gives a strong *potassium* flame; *much water* in closed tube. After ignition on charcoal the residue gives a *magnesium* reaction (pink) with cobalt nitrate. Found principally in the Stassfurt salt deposit.

d. Deflagrate when heated on charcoal, *nitrates.*

SODA NITER, $NaNO_3$, III R. Colorless. Gives an intense yellow *sodium* flame. Found in certain arid regions as Chili (Tarapaca desert).

Niter. Potash niter, KNO_3, IV. Colorless. Gives an intense *potash* flame. Found in certain cave deposits.

e. Heated with fluorite and potassium bisulphate (boron reagent) on the platinum wire gives a deep green flame for *boric acid.*

BORAX, $Na_2B_2O_7.10H_2O$, V. Colorless. On platinum wire *first swells* and then fuses to a clear glass. Gives much water in a closed tube. With turmeric paper, the boric acid reaction (see general reactions of the elements). In salt lake deposits.

Section ii. Insoluble or very slightly soluble in water.

a. Heated on charcoal with soda in the reducing flame give a *sulphur* reaction when placed upon silver and moistened: the silver becoming black by formation of sulphide.*

BARITE, $BaSO_4$, IV. Colorless, or variously colored by impurities. Imparts a *yellowish green color* to the flame, characteristic of *barium.* Gives no water in a closed tube. Insoluble in hydrochloric acid. A common gangue mineral in veins of the heavy metals. Called barytes, heavy spar; used for white paint and as an adulterant for paint.

**It is well to mix the mineral and soda with a little powdered charcoal to facilitate the reduction to sulphide.*

CELESTITE, $SrSO_4$, IV. Colorless, bluish, reddish. Colors the flame *scarlet*, best seen on moistening with HCl; characteristic of *strontium*. Gives no water in closed tube. Nearly insoluble in hydrochloric acid. A source of strontium salts.

ANHYDRITE, $CaSO_4$, IV. Colorless, gray, reddish. Alone, *no decided flame color*. Gives *no water* in closed tube. Slowly dissolves in diluted HCl on boiling; the solution gives a yellowish-red color to the flame, often not very distinct. Occurs in some salt deposits.

GYPSUM, $CaSO_4.2H_2O$, V. Colorless, white; soft, easily scratched with the nail. Gives *much water* in a closed tube. Alone, *no decided flame color*. Readily dissolves in diluted HCl on boiling, the solution giving a yellowish-red calcium flame, often not very distinct. Gypsum is used for making plaster of Paris, etc.; or when compact, as alabaster, for an ornamental stone.

Glauberite, $Na_2SO_4.CaSO_4$, V. Colorless, gray; colors the flame *deep yellow*. Fused *alone* on charcoal R. F. gives a sulphur reaction. Partially soluble in water, readily soluble in dilute HCl on boiling. Occurs in some salt deposits.

Some of the magnesium sulphates are not easily soluble in water, see Section i.

b. Effervesce when treated with acids but do not give the sulphur reaction as above.

WITHERITE, $BaCO_3$, IV. Colorless, gray. Colors the flame *yellowish green* (*barium*). Gives no water in closed tube. A source of barium salts.

Gaylussite, $Na_2CO_3.CaCO_3.5H_2O$, V. Colorless, gray. Colors the flame *deep yellow* (*sodium*). In boiling water it is partially soluble, the solution is alkaline.

Gives water in the closed tube. Found in some salt deposits.

c. Heated with potassium bisulphite or fused salt of phosphorus in a closed tube evolve hydrofluoric acid which etches the glass tube; best seen after cleaning and drying the tube.

FLUORITE, CaF_2, I. Various colors; cleavage octahedral, perfect. Generally decrepitates and when gently heated in a closed tube, *phosphoresces*, but yields no water. When fused gives a *yellowish red flame*. A gangue mineral and alone in considerable deposits; the source of hydrofluoric acid for glass etching, etc.

CRYOLITE, Na_3AlF_6, V. Colorless, resembling snowy ice. Fuses very readily, coloring the flame *intense yellow* (*sodium*). Gently heated in closed tube does not phosphoresce, and yields no water. After long heating on charcoal a white mass is obtained, which with cobalt nitrate, gives a blue color on ignition (*aluminium*). From Greenland, etc.; a source of soda and aluminium.

Thomsenolite, $NaCaAlF_6.H_2O$. Colorless, brownish, generally in square prismatic crystals. In closed tube does not phosphoresce, but decrepitates and gives water, which is acid; generally the tube is etched. Colors the flame *yellow* (*sodium*). *Pachnolite* is a similar compound. Occurs with cryolite in Greenland.

Some of the minerals of Division 1 give only a faint alkaline reaction; such are Epsomite, Kieserite and Kainite. Some aluminium and other sulphates swell and seem to fuse at first but finally give an infusible mass.

Division 2.—Soluble in hydrochloric acid (some also in water) without perceptible residue; the hydrochloric acid solution does not form a jelly upon evaporation.

a. Soluble in hydrochloric acid with evolution of H_2S.

ALABANDITE, MnS, I, tetrahedral. Color brownish or greenish black, *streak green.* The roasted mineral gives the reaction for *manganese* in the borax bead. The luster is submetallic, hence the mineral may be also classed with the *minerals with metallic luster.* Occurs with some copper ores.

b. Fused with metallic magnesium and sodium carbonate in a closed tube yield a mass which when placed in water evolves *phosphine*, recognized by its characteristic disagreeable odor.

APATITE, $Ca_5(Cl,F,)(PO_4)_3$, III. Generally green, blue or colorless, also colored by mechanical impurities. The HCl solution, if concentrated, gives a precipitate upon addition of H_2SO_4. Slight reactions for chlorine and fluorine may be detected. The fusibility is high, the mineral only rounding on thin edges. Apatite (phosphorite, phosphate rock), is the principal source of phosphoric acid for fertilizers, etc.

Amblygonite, $Li[Al(F.OH)]PO_4$, VI. Colorless. white, grayish; cleavage basal, luster pearly. Fuses easily *with intumescence*, generally colors the flame *carmine red*, but may contain sodium, when the flame is yellowish red. Dissolves slowly in HCl. In closed tube gives water, which is acid and etches the glass. Not common.

Herderite, $Ca[Be(F.OH)]PO_4$, IV. Yellowish, greenish. Carefully heated in closed tube *phosphoresces with an orange light*, and on intense heating yields water, which has an acid reaction and etches the tube. Fuses with difficulty, becoming opaque white. Rather rare.

Autunite, $Ca(UO_2)_2(PO_4)_2.8H_2O$, IV. Lemon yellow, pearly-*subadamantine.* With salt of phosphorus in O. F. *yellow, and in R. F.* an emerald-green bead (uranium).

The HCl solution is precipitated by H_2SO_4 (*calcium*). Ammonia added to the solution in HNO_3 throws down a yellow precipitate (*uranium*). The mineral is an alteration product of pitch-blende.

c. Heated on platinum wire with the boron reagent (potassium bisulphate and calcium fluoride) give the green flame for *boric acid.*

BORAX, $Na_2B_2O_7.10H_2O$, V. Colorless. Soluble in water. Fuses with *swelling* to a clear glass and gives a sodium flame. Yields much water in a closed tube. In salt lake deposits.

Sassolite, $B(OH)_3$, VI. Colorless, scaly and pearly. Fuses and slowly volatilizes, coloring the flame green. In some hot-spring deposits.

Boracite, $Mg_7Cl_2B_{16}O_{30}$, I. Colorless; in cubes, dodecahedra, etc. Fuses readily, coloring the flame *green*. In a bead of salt of phosphorus, saturated with copper oxide, it colors the flame azure blue (chlorine). Gives no water in closed tube. In some salt deposits.

COLEMANITE, $Ca_2B_6O_{11}.5H_2O$, V. Colorless, generally well crystallized. In the dilute HCl solution after addition of ammonia in excess, ammonium oxalate gives a precipitate (calcium). Fusible, coloring the flame *green*. In some salt deposits, a source of boric acid.

Sussexite, $H(Mn,Mg,Zn)BO_3$, IV, fibrous. White, gray. Gives a *manganese* bead with borax, and heated alone colors the flame *green*. Rare.

d. In closed tube with charcoal and Na_2CO_3 an *arsenic* mirror on strong ignition.

Pharmacolite, $HCaAsO_4.2H_2O$, V, fibrous. White. The concentrated HCl solution is precipitated by addition of a drop of dilute H_2SO_4 (calcium). In the closed tube gives water. Rare.

Adamite, $Zn(ZnOH)AsO_4$, IV. Pale green yellowish; in crusts and radiating groups of crystals. With Na_2CO_3 on charcoal a coating of zinc oxide, white, becoming green on ignition after moistening with cobalt nitrate. In the closed tube a moderate amount of water which is given off at high temperature. Rare.

Division 3.—Soluble in hydrochloric acid, forming a jelly upon evaporating nearly to dryness.

Section i. In the closed tube give water.

a. Fuse with swelling or frothing when heated B. B.

DATOLITE, $Ca(BOH)SiO_4$, V. Colorless or greenish, very vitreous. Fuses with *slight frothing* to a clear glass, coloring the flame *green* (*boric acid*). But little water in the closed tube, given off at a high temperature. Occurs as a secondary mineral with zeolites, calcite, etc., in basic rocks.

Cancrinite, $H_6(Na_2Ca)_4(NaCO_3)_2Al_6Si_9O_{36}$, III. Yellow, gray, white, generally massive. *Effervesces* when dissolved in hot HCl, and forms a jelly. Fuses with *swelling and frothing* to a white blebby glass, coloring the flame intense *yellow* (*sodium*). Occurs with nepheline, sodalite, etc., in nepheline syenites. Not common.

Scolecite $Ca[Al(OH)_2]Al(SiO_3)_3.2H_2O$, V. Colorless, white. Fuses with swelling, or sometimes *twists into vermicular shapes* during fusion, and becomes a white blebby glass. Gives water in a closed tube at low temperature. Becomes pyroelectric on heating. A zeolite which occurs in altered basalts, etc.

Closely related is *mesolite*, intermediate in composition between scolecite and natrolite (below). It
less swelling and gives a sodium flame; not

Thomsonite $(CaNa_2)_2Al_4(SiO_4)_4.5H_2O$, IV. Colorless, gray. Fuses readily with *swelling* to a white blebby glass, and colors the flame *yellow (sodium)*. Not pyroelectric. After separation of the silica by evaporation to dryness, ammonia gives a white precipitate of $Al(OH)_3$, and if some of the clear solution is decanted after this precipitate settles, ammonium oxalate produces in it a precipitate of calcium oxalate. A zeolite occurring in altered basic rocks.

Laumontite has a similar composition and reactions but does not give a strong sodium flame when fused B. B. Its crystals are obliquely terminated prisms.

a. Fuses without swelling or frothing when heated B. B.

NATROLITE. $Na_2Al(AlO)(SiO_3)_3.2H_2O$, IV and V. Colorless or white. *Fuses quietly* to a clear glass when heated B. B., coloring the flame intense *yellow (sodium)*. On treating as described under Thomsonite to separate the aluminium, ammonium oxalate gives little or no precipitate in the clear filtrate.

A number of zeolites give an imperfect jelly or only gelatinize very slightly with hydrochloric acid; such are analcite, apophyllite, phillipsite, etc. These will be found under Division 4.

Section ii. In the closed tube give little or no water.

a. Fuse with intumescence.

ALLANITE. $Ca_2(AlOH)(Al,Fe,Ce)_2(SiO_4)_3$, V. Color pitchy black, streak greenish gray. Fuses with *swelling and frothing* to a black glass. The cerium group may be examined for as given under Allanite, Division 4. A rock-making mineral in some granites, syenites and gneisses.

Melilite $(Ca,Mg,Fe)_7Al_2(SiO_4)_5$, II. Yellowish, brown-

ish, greenish. In short, square prisms. Fuses with *moderate intumescence* to a greenish glass. Gives iron in the borax bead. A rock-making mineral in some lavas.

b. Fused with excess of soda on charcoal gives a *sulphur* reaction on a silver coin.

Lazurite, Lapis Lazuli. $(Na_2,Ca)_2[(Cl,NaS_3,NaSO_4)Al]Al_2(SiO_4)_3$, I. *Deep ultramarine blue.* Massive. When dissolved in HCl evolves *hydrogen sulphide*, recognizable by its odor. Fuses with some difficulty and colors the flame intense yellow (*sodium*). Rare. Prized as an ornamental stone.

Hauynite, $Na_2Ca(Al.NaSO_4)Al_2(SiO_4)_3$, I. Pale blue, green, whitish. *Does not evolve H_2S* when dissolved in HCl, but barium chloride gives a precipitate of $BaSO_4$ in this solution. Fuses with some difficulty, giving a sodium flame. Closely related is *nosean* or *noselite*, which contains more calcium. The calcium and aluminium may be shown by qualitative separations. These are rock-forming minerals, found in the nepheline rocks.

c. In a salt of phosphorus bead saturated with CuO give a *chlorine* reaction (color the flame blue).

SODALITE, $Na_4(AlCl)Al_2(SiO_4)_3$, I. Blue, greenish, gray. Fuses with some difficulty to a colorless glass, coloring the flame *intense yellow*, due to sodium. In the HCl solution, from which the silica has been separated by evaporation to dryness, ammonia throws down a white precipitate of $Al(OH)_3$. A rock-forming mineral found in Elaeolite syenite.

Eudialyte. A complex silico-zirconate of Ca, Fe, Na, Ce, Mn, containing chlorine in small amount, III. Reddish, brownish. B. B. fuses to a yellowish-green

bead. The diluted HCl solution colors turmeric paper orange (see reactions of zirconium). Rare.

d. In the soda bead a *manganese* reaction.

Tephroite. Mn_2SiO_4, IV. Color grayish, pinkish-gray, often cleavable at right angles. Fuses with some difficulty to a black slag. Generally contains some iron. Occurs with the zinc ores at Franklin, N. J., in Sweden, etc.

WILLEMITE, Zn_2SiO_4, III. Manganese may replace some of the zinc. Various shades of red, yellow, brown and green. *Fuses with difficulty* (sometimes infusible; forms a white enamel. Heated with powdered charcoal and some soda on charcoal gives a *zinc* coating, which on addition of cobalt nitrate and further ignition assumes a *bright green* color on cooling. A valuable zinc ore; found at Franklin, N. J. The manganiferous variety is called *Troostite.*

e. Not included in the foregoing divisions.

NEPHELITE, *Nepheline*, $(Na_2,K_2,Ca)_4Al_8Si_9O_{34}$, III. Colorless, white, gray, luster greasy. Very easily soluble in HCl. Fuses rather readily, coloring the flame *intense yellow* (*sodium*). In the HCl solution after separation of the silica by evaporation to dryness, ammonia precipitates flocculent $Al(OH)_3$, but in the filtrate from this ammonium oxalate gives little or no precipitate. A rock-making mineral in phonolites, elaeolite syenites and nepheline basalts. *Elaeolite* is the plutonic representative of the volcanic nepheline.

ANORTHITE, $Ca_2Al_2Si_2O_8$, VI. White, colorless. Soluble with difficulty in HCl. Fuses with difficulty, and *gives little or no color to the flame.* After separating the

silica and alumina, ammonium oxalate gives an abundant precipitate. A rock making mineral, a variety of plagioclase feldspar.

Schorlomite. $Ca_3(Fe,Ti,Al)_2[(SiTi)O_4]_3$, I. Color pitchy black, sometimes tarnished. The hydrochloric acid solution when boiled with tin assumes a *violet color* (*titanium*). Fuses quietly and readily to a black glass. In the borax bead reacts for iron; in salt of phosphorus, R. F., a violet bead indicating titanium.

Division 4.—Dissolve in hydrochloric acid, the silica separating (in a pulverulent form) without forming a perfect jelly.

Many must be finely pulverized before being treated with acid. In order to determine whether the mineral has been decomposed, the residue not soluble in acid may be tested with a glass rod; if gritty it indicates that decomposition is not complete. A few drops of the clear solution evaporated on a watch glass should give a residue if the mineral has been decomposed. If a portion of the solution is made alkaline with ammonia and sodium phosphate added, a precipitate indicates that the mineral has been attacked by the acid.

Section i.—B. B. in a closed tube give water.

a. Swell, exfoliate or intumesce when fused B. B.

APOPHYLLITE, $H_{14}K_2Ca_8(SiO_3)_{16}.9H_2O$, II. Colorless greenish, pinkish. Basal cleavage and pearly lustre on basal surface. Fuses easily with *some swelling* to a white blebby enamel, giving at the same time the *lilac potash flame.* After separating the silica, ammonia gives no precipitate in the HCl solution, but ammonium oxalate *gives a white precipitate* of calcium oxalate. This zeolite *is a secondary* mineral in basic igneous rocks.

Gives water in the closed tube. Found in some salt deposits.

c. Heated with potassium bisulphite or fused salt of phosphorus in a closed tube evolve hydrofluoric acid which etches the glass tube; best seen after cleaning and drying the tube.

FLUORITE, CaF_2, I. Various colors; cleavage octahedral, perfect. Generally decrepitates and when gently heated in a closed tube, *phosphoresces*, but yields no water. When fused gives a *yellowish red flame*. A gangue mineral and alone in considerable deposits; the source of hydrofluoric acid for glass etching, etc.

CRYOLITE, Na_3AlF_6, V. Colorless, resembling snowy ice. Fuses very readily, coloring the flame *intense yellow (sodium)*. Gently heated in closed tube does not phosphoresce, and yields no water. After long heating on charcoal a white mass is obtained, which with cobalt nitrate, gives a blue color on ignition (*aluminium*). From Greenland, etc.; a source of soda and aluminium.

Thomsenolite, $NaCaAlF_6.H_2O$. Colorless, brownish, generally in square prismatic crystals. In closed tube does not phosphoresce, but decrepitates and gives water, which is acid; generally the tube is etched. Colors the flame *yellow (sodium)*. *Pachnolite* is a similar compound. Occurs with cryolite in Greenland.

Some of the minerals of Division 1 give only a faint alkaline reaction; such are Epsomite, Kieserite and Kainite. Some aluminium and other sulphates swell and seem to fuse at first but finally give an infusible mass.

Division 2.—Soluble in hydrochloric acid (some also in water) without perceptible residue; the hydrochloric acid *solution does* not form a jelly upon evaporation.

a. Soluble in hydrochloric acid with evolution of H_2S.

and green shades are common. All *exfoliate to many times the original size, becoming pearly to submetallic*, often bronzy after heating.

PREHNITE, $H_2Ca_2Al_2(SiO_4)_3$, IV. Pale greenish, gray, white. Gives but little water in closed tube at high temperature. Fuses with *swelling* to a blebby opaque mass. Decomposed by HCl with difficulty. Prehnite occurs in crusts with a radiating structure. With zeolites in altered basic igneous rocks, as basalt, diabase, gabbro, etc.

b. Fuse quietly B. B.; some with difficulty.

ANALCITE, $NaAlSi_2O_6.H_2O$, I. In trapezohedrons, like garnet. Colorless, luster vitreous. Heated B. B. becomes white opaque as it loses water, finally fuses quietly to a clear glass, coloring the flame strong *yellow* (*sodium*). The HCl solution after separation of the silica gives a precipitate of $Al(OH)_3$ with ammonia. A zeolite, found in altered basalts, etc.

DEWEYLITE, $H_4Mg_4Si_3O_{12}.4H_2O$; SERPENTINE, $H_4(Mg, Fe)_3Si_2O_9$; *Sepiolite, meerschaum*, $H_4Mg_2Si_3O_{10}$, are all compact or amorphous. Fusible with difficulty. In the HCl solution, after separation of silica and dilution, ammonia and ammonium carbonate give no precipitate, but addition of salt of phosphorus causes an abundant white precipitate (magnesium). Deweylite looks like a gum or hard glue; it is generally gray or brownish. Meerschaum is light, and generally looks earthy or chalky; it absorbs water and sticks to the tongue. Serpentine is generally greenish, compact, but sometimes fibrous in the serpentine asbestus (common asbestus of commerce), which is called chrysotile. These mi-

The HCl solution is precipitated by H_2SO_4 (*calcium*). Ammonia added to the solution in HNO_3 throws down a yellow precipitate (*uranium*). The mineral is an alteration product of pitch-blende.

c. Heated on platinum wire with the boron reagent (potassium bisulphate and calcium fluoride) give the green flame for *boric acid.*

BORAX, $Na_2B_2O_7.10H_2O$, V. Colorless. Soluble in water. Fuses with *swelling* to a clear glass and gives a sodium flame. Yields much water in a closed tube. In salt lake deposits.

Sassolite, $B(OH)_3$, VI. Colorless, scaly and pearly. Fuses and slowly volatilizes, coloring the flame green. In some hot-spring deposits.

Boracite, $Mg_7Cl_2B_{16}O_{30}$, I. Colorless; in cubes, dodecahedra, etc. Fuses readily, coloring the flame *green.* In a bead of salt of phosphorus, saturated with copper oxide, it colors the flame azure blue (chlorine). Gives no water in closed tube. In some salt deposits.

COLEMANITE, $Ca_2B_6O_{11}.5H_2O$, V. Colorless, generally well crystallized. In the dilute HCl solution after addition of ammonia in excess, ammonium oxalate gives a precipitate (calcium). Fusible, coloring the flame *green.* In some salt deposits, a source of boric acid.

Sussexite, $H(Mn,Mg,Zn)BO_3$, IV, fibrous. White, gray. Gives a *manganese* bead with borax, and heated alone colors the flame *green.* Rare.

d. In closed tube with charcoal and Na_2CO_3 an *arsenic* mirror on strong ignition.

Pharmacolite, $HCaAsO_4.2H_2O$, V, fibrous. White. The concentrated HCl solution is precipitated by addition of a drop of dilute H_2SO_4 (calcium). In the closed tube gives water. Rare.

oxalate). A secondary mineral in some altered limestones, etc.

TITANITE, SPHENE, $CaTiSiO_5$, V. Brown, greenish, yellowish; luster high, resinous to adamantine. Fusible with some difficulty and with *slight intumescence* to a brownish or black glass; does not give a decided color to the flame. Slowly attacked by HCl, the solution boiled with tin becomes *violet* colored (*titanium*). A rock-forming mineral in granitoid and gneissic rocks, also in altered limestones.

b. Fuse quietly B. B.

LABRADORITE, $NaAlSi_3O_8.3CaAl_2Si_2O_8$, VI. Gray, greenish, white; luster vitreous, sometimes with a play of colors. Cleavable in two directions nearly at right angles. Parallel striations generally show on one cleavage face. Fusible with some difficulty, without intumescence, to a clear globule, giving a *sodium flame*. Dissolves slowly in boiling HCl with separation of silica. Reacts for Al and Ca as with Wernerite, above. An important rock-making feldspar, *plagioclase*.

WOLLASTONITE, $CaSiO_3$, V. White, gray; luster vitreous, sometimes pearly. Cleavage pinacoidal, strong. The mineral often looks somewhat fibrous in texture. Fuses with some difficulty, gives no decided color to the flame. Rather easily decomposed by boiling HCl. *No aluminium* is shown by addition of ammonia, but in the ammoniacal solution, ammonium oxalate gives a white precipitate (*calcium* oxalate). Found in altered limestones, etc.

***Division 5.—Insoluble* in hydrochloric acid or but very slightly attacked.**

a. Give the reddish amethyst color of *manganese* in the borax bead *O. F.*

Thomsonite $(CaNa_2)_2Al_4(SiO_4)_4.5H_2O$, IV. Colorless, gray. Fuses readily with *swelling* to a white blebby glass, and colors the flame *yellow (sodium)*. Not pyroelectric. After separation of the silica by evaporation to dryness, ammonia gives a white precipitate of $Al(OH)_3$, and if some of the clear solution is decanted after this precipitate settles, ammonium oxalate produces in it a precipitate of calcium oxalate. A zeolite occurring in altered basic rocks.

Laumontite has a similar composition and reactions but does not give a strong sodium flame when fused B. B. Its crystals are obliquely terminated prisms.

a. Fuses without swelling or frothing when heated B. B.

NATROLITE. $Na_2Al(AlO)(SiO_3)_3.2H_2O$, IV and V. Colorless or white. *Fuses quietly* to a clear glass when heated B. B., coloring the flame intense *yellow (sodium)*. On treating as described under Thomsonite to separate the aluminium, ammonium oxalate gives little or no precipitate in the clear filtrate.

A number of zeolites give an imperfect jelly or only gelatinize very slightly with hydrochloric acid; such are analcite, apophyllite, phillipsite, etc. These will be found under Division 4.

Section ii. In the closed tube give little or no water.

a. Fuse with intumescence.

ALLANITE. $Ca_2(AlOH)(Al,Fe,Ce)_2(SiO_4)_3$, V. Color pitchy black, streak greenish gray. Fuses with *swelling and frothing* to a black glass. The cerium group may be examined for as given under Allanite, Division 4. A rock-making mineral in some granites, syenites and gneisses.

Melilite $(Ca,Mg,Fe)_7Al_2(SiO_4)_5$, II. Yellowish, brown-

iron reaction. After fusion gelatinizes with HCl. A rock-forming mineral in some schists and gneisses, also in altered limestones.

b. Gives a sapphire-blue bead with salt of phosphorus R. F. (*tungsten*).

SCHEELITE, $CaWO_4$, II. White yellowish, brownish, *very heavy* (G = 6.05). Fuses with much difficulty. Decomposed by boiling HCl with separation of yellow WO_3. In the solution ammonia gives no precipitate, but in this ammoniacal solution ammonium oxalate gives a white precipitate of calcium oxalate. The yellow residue, boiled with tin and HCl, colors the solution *sapphire blue*. A source of Tungsten compounds. Compare also *Titanite*, which gives a *violet* bead with salt of phosphorus R. F.

c. Alone or with Turner's boron reagent (fluorspar and potassium bisulphate) impart a *green* color to the flame (*barium*, *boron*).

Harmotome, $(Ba,K_2)Al_2Si_5O_{14}.5H_2O$, V. In cross shaped twin crystals. Colorless or white, gray. Gives a *yellow green color* to the blowpipe flame when fused alone. Slowly decomposed with hydrochloric acid; in this solution, sulphuric acid precipitates $BaSO_4$, white, pulverulent. Ammonia in the HCl solution throws down gelatinous $Al(OH)_3$. A zeolite.

Danburite, $CaB_2(SiO_4)_2$, IV. White, yellowish. Heated alone B. B. colors the flame *fine green* (boric acid) and fuses rather easily to a bead which is clear when hot but cloudy when cold. Generally phosphoresces when heated with a reddish light. After fusion gelatinizes with HCl. Rather rare.

AXINITE, $H(Ca,Fe)_4(Al,B)_3(HAlSiO_4)(SiO_4)_4$, VI.

Brown, gray, yellow, greenish. Fuses easily, with *bubbling*, sometimes coloring the flame *green;* this green color is always obtained on treating with the boron reagent. After fusion, gelatinizes with HCl; not attacked before fusion. A rather rare borosilicate.

TOURMALINE, $(H_2,Li_2Na_2,Fe,Mg,[AlO]_2)_3(AlO.BO)(SiO_4)_2$, III R. Black, brown, green; also pink, bluish, white. *In striated prisms with more or less triangular section.* Heated B. B. fuses with *bubbling*, usually easily, to a slaggy mass or globule. A fragment or crystal heated B. B. *exhibits pyroelectricity*, attracting small pieces of paper, etc. The green flame is generally only seen when the mineral is heated, after being mixed with the boron reagent. A common rock-making mineral in schists, slates, gneisses, etc., also in altered limestones and granites.

d. Heated alone in the forceps B. B. impart a *carmine* color to the flame, indicating *lithium*.

LEPIDOLITE, *Lithia mica*, $(F,OH)_2(Li,K)_2Al_2Si_3O_9$, V. Lilac, purplish, also grayish; micaceous, generally compact scaly; luster pearly. Fuses readily, *with intumescence* to a grayish glass, and gives the *lithium flame.* In closed tube yields water on intense ignition which has an acid reaction and sometimes etches the glass. Rather abundant in some parts of Maine, Massachusetts and California. *Zinnwaldite* has similar reactions but fuses to a black glass, which is generally magnetic after heating R. F.

Petalite, $LiAl(Si_2O_5)_2$, V. Colorless, white, gray. Strong basal cleavage. Sometimes phosphoresces when gently heated; when strongly heated whitens and fuses with some difficulty to an enamel. Sometimes con-

tains sodium, which may somewhat obscure the flame reaction for lithium. Rather rare.

SPODUMENE, $LiAlSi_2O_6$, V. Grayish to greenish white, rarely emerald-green (Hiddenite). Perfect prismatic cleavage, often looks silky in luster. Heated B. B. whitens and often *swells or splits*, fuses quite readily, giving the *lithium flame*. Found in granites, etc.

Amblygonite, $Li[Al(F,OH)]PO_4$, VI. White, greenish, yellowish, grayish; luster pearly to greasy, basal cleavage perfect. Fuses easily with *intumescence*, becoming opaque white. Colors flame *red or yellowish red*, the yellow due to Na sometimes present. With soda and metallic magnesium in closed tube a phosphate reaction. In closed tube gives water, at high temperature, which water is acid. In granite, rather rare.

e. Strongly cleavable in one direction, micaceous, foliated. Hardness under 4.5, scratched by a wire nail. This group includes the *micas*.

Margarite, $H_2CaAl_4Si_2O_{12}$, V. Pinkish, gray; luster pearly. Often in crusts. Harder than most micas, *brittle*. Heated in the forceps, whitens and fuses with some difficulty, does not color the flame decidedly. Gives water in the closed tube when intensely ignited, somewhat attacked by boiling HCl. Occurs with corundum or emery, often altered from corundum.

MUSCOVITE, $H_2(K,Na)Al_3(SiO_4)_3$, V. *Colorless* in thin plates, brownish, gray, greenish; vitreous or sometimes pearly. *Folia elastic*. Heated B. B. whitens and fuses with much difficulty to a grayish glass, generally gives a potash flame. Gives some water at high temperature in the closed tube. *Not affected by boiling HCl or* H_2SO_4.

Muscovite or white mica is a common rock-making mineral in granites, gneisses, schists, etc.; used for electric insulation.

BIOTITE, $(H,K)_2(Mg,Fe)_2(Al,Fe)_2(SiO_4)_3$, V. Black, greenish, brownish; high vitreous to splendent. *Folia elastic.* Heated B. B. becomes light colored and pearly, fusing only on the edges. *Decomposed by boiling sulphuric acid.* Gives a little water at high temperature in closed tube. A common rock-making mineral in igneous rocks, in gneisses, schists, etc.

PHLOGOPITE, $(K,H)_3Mg_3Al(SiO_4)_3$, V. Contains a small (varying) amount of iron, and sometimes approaches biotite in composition. Generally brownish, yellowish or greenish, luster pearly. *Elastic.* Fuses with difficulty, becoming very pearly when heated. In the closed tube a little acid water at high temperature, the acidity being due to fluorine which is present in small quantity. *Boiling H_2SO_4 completely decomposes phlogopite.* Found in altered magnesian limestones.

CHLORITES. *Clinochlore*, *Ripidolite*, *Penninite*, etc. About $H_{20}Mg_{12}Al_6Si_7O_{45}$, V. Green, vitreous, sometimes pearly; *not elastic*, but folia easily flexible; easily scratched by the finger nail. At high temperature *in closed tube gives much water.* B. B. in the forceps becomes pearly, and fuses with difficulty to a dark glass. Contains enough iron to give a reaction in the borax bead. *Completely decomposed by boiling H_2SO_4.* Chlorites are common alteration products of the ferro-magnesian minerals of igneous rocks.

TALC, $H_2Mg_3Si_4O_{12}$, V. White, gray, greenish; luster glistening to pearly. *Very soft and greasy to the touch; flexible in thin plates*, but not elastic. Not attacked by

acids. B. B. whitens and fuses, with difficulty, on the edges to a white enamel. In closed tube at high temperature a little water. With cobalt nitrate a magnesium reaction, pink. Varieties of talc are *soapstone* and *steatite.* An alteration of chrysolite, pyroxene and other magnesian silicates, also of dolomite.

f. Feldspar group, mostly light-colored minerals, cleaving in two directions nearly or exactly at 90°. Hardness of the group about that of steel.

ORTHOCLASE, SANIDINE, $KAlSi_3O_8$, V. MICROCLINE, $KAlSi_3O_8$, VI; *Anorthoclase*, $(Na,K)\ AlSi_3O_8$, VI, pseudo-monoclinic. Orthoclase is the plutonic mineral representing sanidine, the volcanic mineral. Microcline develops from the others under pressure. Cleavage angle of orthoclase and sanidine 90° exactly, microcline 89° 30′. Colorless, white, reddish, gray, buff, green. Sanidine is generally glassy, the others more dull. The *sodium*, when present, colors the flame *intense yellow.* The *potassium* may be shown by fusing on a wire with gypsum or calcium fluoride. Heated B. B. fuse with difficulty in thin splinters or on thin edges to a clear glass. *Not attacked by acids.* Important rock-making minerals in the acid igneous rocks; used in making porcelain.

PLAGIOCLASE FELDSPARS including ALBITE, $NaAlSi_3O_8$; OLIGOCLASE, $3NaAlSi_3O_8.CaAl_2Si_2O_8$; ANDESITE, $NaAlSi_3O_8.CaAl_2Si_2O_8$; LABRADORITE, $NaAlSi_3O_8.3CaAl_2Si_2O_8$; ANORTHITE, $CaAl_2Si_2O_8$, all are triclinic with cleavage angles of 86°–86° 30′. The faces are generally *striated with fine parallel lines.* Fusible with difficulty B. B. but *more easily fused* than the orthoclase group. Color the flame *intense yellow* (*sodium*). The calcium and alumin-

ium may be shown after separation of the silica (which is done by fusing with soda and evaporating with HCl) by throwing down *aluminium* as flocculent white hydrate with ammonia, and then to the filtrate from this precipitation adding ammonium oxalate, which throws down *calcium* as white oxalate. The relative amount of calcium will indicate which member of the series is being examined. The plagioclase feldspars are generally white, colorless, gray or greenish. They are important rock-making minerals in the basic and intermediate rocks; albite and oligoclase are used in porcelain making.

g. Pyroxene group. Generally dark-colored silicates which cleave more or less readily in two directions at angles of 93° and 87°. Fuse quietly and usually rather easily. Hardness 5.5–6.5.

PYROXENE, $Ca(Mg,Fe)Si_2O_6$, V. Blackish-green to lighter green; vitreous. B. B. fuses without difficulty to a slag which may be *brownish* or *greenish*. Generally not acted upon by acids. Found principally in metamorphosed rocks. Often has a very well-developed basal parting. This includes *Fassaite*. *Hedenbergite* has more iron and less magnesium.

AUGITE, $Ca(Fe,Mg)Si_2O_6.(Fe,Mg)Al_2SiO_6$, V. Color black, greenish and brownish-black. Often in eight-sided crystals. Fuses quietly but sometimes with some difficulty to a *black glassy slag*. Contains iron, replacing the Mg and Al, gives the iron reaction in the borax bead. Occasionally becomes magnetic on heating R. F. and then would belong in Division 5 of Part A. Augite is the principal rock-making pyroxene in igneous rocks.

DIOPSIDE, $CaMgSi_2O_6$, V. Pale green to colorless. *Fuses without* difficulty to a colorless or pale glass.

Recognized by its color and cleavage. Often in altered limestones. A pale pyroxene similar to Diopside in color is *Jadeite*, $NaAlSi_2O_6$, V, which fuses to a blebby slag and colors the flame intense yellow, due to the sodium.

Compare *enstatite*, which is only fusible above 5.

h. Amphibole group. Generally with strong cleavage in two directions, at 56° and 124° with each other, readily fusible, sometimes with intumescence, to a glass.

HORNBLENDE, $Ca(Mg,Fe)_3(SiO_3)_4.Al_2(Mg,Fe)_2(SiO_3)_2(AlO_3)_2.Fe_2(Mg,Fe)_2(SiO_3)_2(FeO_3)_2$, V. Greenish-black to green. Fuses easily, or without much difficulty, generally with some intumescence to a *black glassy globule*. Often colors the flame yellow, due to sodium. Gives an iron reaction in the borax bead. May contain enough iron to become magnetic after heating R. F. Softer than steel, the powder is greenish-gray. A common rock making mineral in igneous and metamorphic rocks.

TREMOLITE, $CaMg_3(SiO_3)_4$, V. Gray, white, rarely violet; generally fibrous if compact, and passing into *asbestus*. Fuses to a *colorless or pale glass*. This includes some compact varieties called *Jade*. Generally found in altered limestones, in serpentine, etc.

ACTINOLITE, $Ca(Mg,Fe)_3Si_4O_{12}$, V. Bright to pale green. Fuses to a *greenish* globule, rarely gives a color to the flame. Many specimens of "Jade" are actinolite. May be also in the fibrous form of asbestus. Found in altered rocks, often with serpentine or chlorite.

Compare *anthophyllite*, which is only fusible above 5.

i. Not included in the foregoing divisions.

GROSSULARITE, $Ca_3Al_2Si_3O_{12}$, I. White, yellowish,

greenish, pale reddish. In dodecahedrons and trapezohedrons; readily recognized as a garnet when in crystals. Fuses quietly and rather easily, gelatinizing with HCl after fusion. Closely allied is the deep red garnet PYROPE, $Mg_3Al_2Si_3O_{12}$, I, which is used as a gem. Grossularite is found in altered limestone, Pyrope occurs commonly in peridotites, basalts and other basic and ultra-basic rocks. The garnets containing considerable iron, as *almandite* and *andradite*, become magnetic upon heating in the reducing flame. *Spessartite* gives a manganese reaction. All are included in the foregoing divisions. The chrome garnet *ouvarovite* is infusible.

EPIDOTE, V., and ZOISITE, IV. $Ca_2(AlOH)Al_2(SiO_4)_3$. In epidote Fe_2 is isomorphous with Al_2. Epidote is generally pistachio green, zoisite is gray or grayish-green, sometimes pink when it contains some Mn. Heated B. B. fuse rather easily *with intumescence* to a slag which does not melt further to a globule except upon intense heating. After fusion both gelatinize with HCl. Both of these minerals show a *perfect cleavage* along the length of the prismatic crystal.

VESUVIANITE $Ca_6Al_2[Al(OH,F)](SiO_4)_5$, II. Color brownish-olive to yellowish-green, also brown, yellow, rarely blue, reddish; luster vitreous, fracture uneven. Heated B. B. fuses rather easily with *intumescence* to a glass, which gelatinizes with HCl. Occurs in metamorphosed limestones.

Compare also *Prehnite* and *Wernerite*, which are slowly acted upon by HCl; also *Beryl*, *Iolite*, *Anthophyllite* and *Enstatite*, which are fusible above 5, or nearly infusible B. B.

Class III.—Infusible, or fusibility above 5.

Division 1.—Assume a fine blue color when, after previous ignition B. B., they are moistened with cobalt nitrate solution and again ignited (alumina).

(Some minerals should be first calcined and pulverized.)

The hardest anhydrous minerals belonging to this class show this color most distinctly after they are finely pulverized and then moistened with cobalt solution and ignited; the color appears as the mass cools, and is distinctly seen only by daylight. A blue *infusible* mass alone indicates *alumina;* if any fusion shows in the mass only *silica* is indicated with certainty.

Section i. B. B. yield water in a closed tube.

a. The water in closed tube is acid and *etches the glass.*

Ralstonite, $3Al(F,OH)_3.(Na_2Mg)F_2.H_2O$, I. In white or colorless octahedrons. Heated B. B. in the forceps whitens, and colors the flame *yellow* (*sodium*). In the closed tube the etching of the glass only occurs on strong ignition, the first water given off at low temperature not affecting the glass. H_2SO_4 decomposes it with liberation of HF. Occurs with Thomsenolite, Cryolite, etc.

Compare *wavellite* below.

b. With soda on charcoal gives a *sulphur* reaction, the fused mass giving a brown or black spot when placed upon a silver coin and moistened.

Kalinite, *Potash Alum*, $KAl(SO_4)_2.12H_2O$, I. Colorless, white. Soluble in water, has an astringent and *sweetish taste.* Heated B. B. whitens and swells,

often after melting somewhat in its water of crystallization, to a porous mass, which treated with cobalt nitrate assumes a deep blue color. Gives much water in a closed tube. The solution gives the wet reactions for aluminium and sulphuric acid. Occurs as an efflorescence on pyritous slates, and in limestone caves.

Aluminite, $Al_2(OH)_4SO_4.7H_2O$, V. White, opaque; compact, luster on fracture is dull. In closed tube much water, which on strong ignition is *acid*, but does not etch the glass. Soluble in acids. Rather rare.

Alunite. $K(Al.2OH)_3(SO_4)_2$, III R. Color white, grayish; massive, compact to fibrous, luster dull. Crystals not common. Heated B. B. decrepitates, without fusing. In closed tube gives water, which when given off at high temperature, is *acid*. Reactions similar to the last, but does not yield so much water. Found in volcanic rocks that have been altered by sulphurous gases. Rather rare.

c. Fused with soda and metallic magnesium in a closed tube yield a mass which, when placed in water, *evolves phosphine*, recognized by its disagreeable odor. *Phosphates.*

WAVELLITE $(AlOH)_3(PO_4)_2.5H_2O$, IV. Colors white, yellow, green, gray, bluish. Generally in fibrous aggregates. In closed tube gives much water, the last portions to come off sometimes contain hydrofluoric acid and etch the glass slightly. Swells and splits up when heated in the forceps, but does not fuse; colors the flame pale greenish. Soluble in HCl, and in KOH. A source of phosphoric acid.

Lazulite $(Mg,Fe)(AlOH)_2(PO_4)_2$, V. Azure blue, *streak* white. Heated B. B. swells and falls to pieces *without fusing*, colors the flame pale greenish. With

soda and metallic magnesium in a closed tube a phosphorus reaction. Not affected by acids. Rather rare.

d. **Not included in the preceding sections.**

CALAMINE ($ZnOH)_2SiO_3$, IV hemimorphic. Colorless, white, green, brownish. In fan-like groups of crystals. *Pyroelectric.* With soda on charcoal a white coating of ZnO, which, treated with cobalt nitrate and again ignited, becomes *green.* Soluble in HCl.

Gibbsite, $Al(OH)_3$, V. Generally stalactitic. Grayish, white; luster dull. Smells of clay. In closed tube whitens and gives water. Soluble in concentrated H_2SO_4. Found with limonite, not common.

BAUXITE, $Al_2O(OH)_4$. Campact or earthy. Bauxite generally contains admixed Fe_2O_3. Colors red, brownish, pink, white, luster dull. Often with an oölitic texture. If not too dark colored due to iron, bauxite gives the blue colored mass characteristic of aluminium, when ignited after moistening with cobalt nitrate. Scarcely soluble in HCl. An ore of aluminium; used also for making alum.

Allophane, $Al_2SiO_5.5H_2O$. Amorphous. Color generally bluish or greenish, due to copper. When heated B. B. *falls to pieces without fusing.* Gelatinizes with HCl. Occurs with limonite, wad and other results of hydration.

HALLOYSITE, $H_4Al_2Si_2O_9.H_2O$. Amorphous or massive. Color white, grayish. Waxy; when placed in water becoming translucent. Absorbs water readily, sticks to the tongue. Decomposed with acid. Used for *making alum* and also for aluminium. Found in *mineral veins.*

KAOLIN, $H_4Al_2Si_2O_9$, V. Generally earthy. White or colored by impurities. Generally becomes plastic when ground with water. *Smells like clay* of which it is the basis. A decomposition product of feldspars, etc. Used for pottery, making alum, etc.

Diaspore, AlO.OH, IV. Whitish, gray, greenish, violet; luster adamantine to pearly. Harder than steel. When heated, generally decrepitates, and in the closed tube at high temperature gives a little water. Not attacked by acids before heating, after ignition soluble in H_2SO_4. Found with corundum.

PYROPHYLLITE, $HAlSi_2O_6$, IV. White, pale green, micaceous, very pearly. Very soft like talc. Often in radiating crystallizations, also compact massive, including *Agalmatolite*. Heated B. B. often swells and exfoliates, but does not fuse. At high temperature water is obtained in the closed tube. The compact varieties usually do not swell when heated B. B. Partially decomposed by boiling H_2SO_4.

Clintonite or *Seybertite*, $H_3(Ca,Mg)_5Al_5Si_2O_{18}$, V. Coppery red to brownish, luster pearly. A brittle mica, not elastic. Heated B. B. becomes lighter and more pearly, but remains infusible. Decomposed by acids when in the form of fine powder. On intense ignition yields a little water in closed tube. Found in altered limestones. Compare also micas, as *muscovite*, which may be nearly infusible and become blue with cobalt nitrate. Some varieties of *Andalusite* by alteration are softer than steel and give a little water. See below.

Section ii.—Give no water in the closed tube.

a. Are softer than steel, may be scratched with a knife. (*Hardness under 6.*)

WILLEMITE, Zn_2SiO_4, III R. All colors, shades of red, green, yellow; also colorless. With cobalt nitrate a fine blue or in some parts a green color. With soda on charcoal a *zinc coating*, yellow when hot, white when cold, which when treated with cobalt nitrate and again ignited assumes a *fine green color* on cooling. Gelatinizes perfectly with HCl. An important ore of zinc.

CYANITE, $(AlO)_2SiO_3$, VI. Blue, colorless, gray, greenish, in long thin bladed crystals, cleavage along length of crystal. The mineral is easily scratched by steel parallel to the length of the crystal, but not across the crystal. Not affected by acids; soluble in a salt of phosphorus bead, leaving a skeleton of silica. In mica schists, gneisses, slates; a rock-forming mineral.

b. **Hardness greater than that of steel, cannot be scratched by a knife. (Hardness above 6.)**

ANDALUSITE, IV, and *Sillimanite*, IV, $Al(AlO)SiO_4$. Andalusite is in square, almost rectangular prisms; Sillimanite generally fibrous. Color gray, reddish, pink, greenish for Andalusite, and gray, brown and greenish for Sillimanite. Some varieties of Andalusite show blackish impurities in the crystals, disposed along the length, so that the cross section shows a cross or similar design (chiastolite). Not acted upon by HCl. In a bead of salt of phosphorus, a fragment slowly dissolves having a skeleton of silica. Andalusite occurs in mica schists, phyllites, slates, also in gneisses; Sillimanite occurs in mica schist and gneiss. Both are rock-making minerals.

TOURMALINE, *Alkali Tourmaline* $[H_2,Li_2,Na_2,(AlO)_2]$ $(AlO.BO)(SiO_4)_2$, *III* R, hemimorphic. Colorless, *pink, reddish, bluish,* greenish; luster vitreous. Heated

B. B. whitens and on very intense ignition shows signs of fusion, *pyroelectric*. With fluorite and potassium bisulphate on the wire a *green flame, due to boron*. Not affected by acids until after intense ignition. Hardness 7–7.5. Associated with Lepidolite and other lithium minerals. Used for a gem.

TOPAZ, $Al_2(F,OH)_2SiO_4$, IV. Colorless, yellow, also bluish, greenish. In closed tube with fused salt of phosphorus a *fluorine reaction*, giving a ring of SiO_2 above the point of heating. Scarcely attacked by sulphuric acid. In gneiss, granite, rhyolite; used for a gem.

BERYL, $Be_6Al_4(SiO_3)_{12}.H_2O$ (Penfield), III. Green, yellow, blue-green to blue, nearly colorless. When blue-green called *aquamarine*, when green *emerald*. Heated B. B. becomes white and sometimes fuses slightly on the thin edges. A small amount of water on intense ignition in closed tube. Not attacked by acids. *Emerald* contains chromium, which is present in sufficient amount to give a reaction with the borax bead. Beryl occurs in granites, gneisses and schists. In clear varieties, valued as a gem.

CORUNDUM, Al_2O_3, III R. Gray, white, yellowish, *corundum;* blue, *sapphire;* red, *ruby*. *The hardest natural terrestrial mineral, excepting diamond*. Heated B. B. alone, unaltered; in salt of phosphorus bead dissolves readily and completely; not attacked by fusing with soda. Not affected by acids; soluble in fused $KHSO_4$. In crystalline igneous and metamorphic rocks. Used as an abrasive, also as a gem.

Chrysoberyl, $Be_2Al_2O_4$, IV. Yellowish green, emerald *green, grayish*. Heated B. B. alone, unaltered; with

alt of phosphorus dissolves with much difficulty, but completely; only slightly affected by fusion with soda. Not attacked by any acids. In granites and gneisses.

Compare also *spinel*, *leucite*, which sometimes give a blue color when ignited with cobalt nitrate. *Cassiterite* gives a greenish-blue color in some cases.

Division 2.—Moistened with cobalt nitrate solution and ignited assume a fine green color on cooling (Zinc).

a. Soluble in diluted boiling HCl *with effervescence.*

HYDROZINCITE $(ZnOH)_2CO_3$, chalky. Color white. Heated in closed tube gives *water*, becomes yellow when hot, but white again upon cooling. Gives off CO_2 when dissolved in HCl. With soda on charcoal a *zinc coating*, yellow when hot, white when cold, which acts as the mineral does with cobalt nitrate. A zinc ore, occurring in deposits near the surface, from alteration of *sphalerite*, etc.

SMITHSONITE, $ZnCO_3$, III R. White, brownish. Yields *no water* in closed tube, otherwise reacts same as the last. Often occurs in crusts, as a surface ore of zinc, the crusts generally have a radiating fibrous structure. Crystals are common, but small. A zinc ore.

SPHALERITE, ZnS, I, tetrahedral. All shades of yellow and brown, reddish, colorless; luster resinous or adamantine; cleavage dodecahedral, perfect. In some varieties submetallic luster is shown. Generally gives a green color with cobalt nitrate. Gives off H_2S when dissolved in HCl. The principal ore of zinc.

b. Gelatinize with HCl but *do not effervesce* while dissolving.

CALAMINE $(ZnOH)_2SiO_3$, IV, hemimorphic. See *Division 1, Sec. i. d.* above. Calamine with cobalt

nitrate shows green and blue in different parts of the same fragment.

WILLEMITE, Zn_2SiO_4, III R. See *Division 1, Sec. ii, a.* above. Willemite, like calamine, may show green or blue in different parts of the fragment treated. Distinguished from calamine by affording no water in the closed tube.

Compare also *Zincite*, *Cassiterite*, which sometimes give a green or bluish-green color with cobalt nitrate.

Division 3.—After strong ignition B. B. a fragment placed upon turmeric paper and moistened gives an alkaline reaction and changes the color of the paper to red-brown ; or placed upon red litmus paper it changes the color to blue.

a. In the closed tube give water.

BRUCITE, $Mg(OH)_2$, III R. Colorless or greenish; has a strong basal cleavage. May be just scratched with the finger-nail. Heated B. B. glows, and, with cobalt nitrate and further ignition, gives a *pink color*. The alkaline reaction is not very marked. Easily and quietly soluble in HCl. Occurs associated with serpentine deposits.

Hydromagnesite, $Mg_2(MgOH)_2(CO_3)_3.3H_2O$, V. White. Soluble in hot HCl with *effervescence*, otherwise gives reactions like those of Brucite. Several other hydrous carbonates of magnesium are known ; all are rare.

b. In the closed tube give no water.

CALCITE, $CaCO_3$, III R. Colorless, white, yellowish, colored by impurities. *Effervesces readily in cold dilute HCl.* Heated B. B. whitens and often decrepitates ; *it glows*, becoming caustic and giving a *strong alkaline reaction* with turmeric paper. Moistened with HCl, colors *the flame reddish-orange* (*calcium*). A fragment placed

in the borax bead dissolves with *effervescence*. The powder boiled with solution of cobalt nitrate remains uncolored or becomes a lavender blue. The rhombohedral carbonates, of which calcite is the type, all possess a strong rhombohedral cleavage at angles of 105°–107°. Calcite is a very common gangue mineral; massive, it forms *limestone* and *marble*.

ARAGONITE, $CaCO_3$, IV. Colorless or colored by impurities as with calcite. Reactions same as with calcite except that the powder, boiled with cobalt nitrate, becomes lilac red; and in closed tube the aragonite often *falls to pieces when heated* to about 400° C., due to change to calcite. *No strong cleavage.* Occurs with *gypsum*, and in altered basic igneous rocks.

DOLOMITE, $(Ca,Mg)CO_3$, III R, tri-rhombohedral. Colorless, gray, pinkish. A fragment is *scarcely attacked by cold dilute HCl* but dissolves readily with strong effervescence in hot HCl. In the solution, after separation of the *calcium* with ammonia and ammonium oxalate, salt of phosphorus gives a white precipitate (*magnesium*). Cleavage as in calcite, *faces of cleavage often curved*, luster inclining to pearly. A gangue mineral and forming *dolomite limestone.*

ANKERITE $(Ca,Mg,Fe)CO_3$, III R. White, yellowish, brownish; weathers rusty. Gives same reactions as dolomite for *calcium* and *magnesium*, but ammonia in the HCl solution, oxidized with a few drops of HNO_3, throws down reddish-brown *ferric hydrate*, $Fe(OH)_3$. Blackens on heating, and in R. F. becomes somewhat magnetic. A gangue mineral.

MAGNESITE, $MgCO_3$, III R. White, gray, yellowish or brownish, often compact. Not much affected by cold

dilute HCl, but soluble in hot acid with effervescence; in this solution ammonia and ammonium oxalate give *no precipitate* (or very little), but salt of phosphorus gives an abundant white precipitate (*magnesium*). The alkaline reaction with turmeric paper is often weak. Associated with *serpentine* and *gypsum*. Closely related is *Breunnerite* $(Mg,Fe)CO_3$, III R, which gives the reactions of *magnesite* and in addition gives the *iron* reaction in the HCl solution (to which a few drops of HNO_3 have been added to oxidize the iron), when ammonia is added in excess. Breunnerite occurs as a gangue mineral, in metalliferous veins.

STRONTIANITE, $SrCO_3$, IV. Columnar. Color greenish, white, gray; cleavage prismatic, fracture columnar or stalky. Heated B. B. *splits and often throws out irregular branches. Colors the flame scarlet* (*strontium*). Soluble with effervescence in dilute HCl. Dilute H_2SO_4 gives a precipitate in this solution. With soda on charcoal fuses to a clear glass, and on further heating is entirely absorbed in the coal. In metalliferous veins, in limestones, and associated with gypsum.

The rare *Barytocalcite* and *Bromlite*, both carbonates of calcium and barium, would belong in this division. They give a yellowish-green flame B. B. Many minerals that occur in limestone as *tremolite*, *apatite*, *chondrodite*, *spinel*, and others, may contain so much calcite as a mechanical impurity, that they give an alkaline reaction when treated as above directed. This should be borne in mind when examining for alkaline reaction as above.

Division 4.—When treated with hydrochloric acid, or, if this has no effect, with nitric acid, the mineral is dissolved without gelatinizing or leaving a residue of silica.

a. **Soluble in the hot acid *with effervescence.***

SPHALERITE, ZnS, I, tetrahedral. Occurs in all shades of yellow and brown, reddish, colorless; luster resinous or adamantine on the dodecahedral cleavage faces. Sometimes very dark, when the luster is submetallic. Usually gives a green color with cobalt nitrate and would hence be found in the preceding division. When dissolved in HCl *gives off* H_2S, recognized by the odor. In open tube SO_2 and odor of burning sulphur, a piece of moistened blue litmus placed in the tube is reddened and bleached. *Wurtzite* is ZnS, III.; it closely resembles sphalerite, but has a fibrous to stalky fracture. *Sphalerite* is the most important ore of zinc; *Wurtzite* is also used as an ore.

Greenockite. CdS, III, hemimorphic. Crystals rare or very minute; usually earthy. Color chrome-yellow or orange. Heated with soda on charcoal a coating of cadmium oxide, brownish, and a sulphur reaction with the soda. Soluble in HCl with evolution of hydrogen sulphide, recognized by the odor. Occurs with sphalerite and other ores of zinc.

SIDERITE, $FeCO_3$, III R, generally brownish-gray, cleavable parallel to the rhombohedron. When heated B. B. generally decrepitates, blackens and in R. F. becomes magnetic. Soluble in HCl *with evolution of* CO_2; the solution reacts for *ferrous iron* with potassium ferricyanide. Soluble in the borax bead with a bottle-green *color, becoming brownish* on heating in O. F. An *important iron ore.* Related to siderite is Breunnerite, which

generally gives an alkaline reaction. See also *Magnesite, Div. 3, b.*

RHODOCHROSITE, $MnCO_3$, III R. Color pink to rose-red, also brownish-red. In crystals and also in crusts, botryoidal, massive cleavable. Cleavage rhombohedral. Heated B. B. blackens or turns gray and in R. F. becomes somewhat magnetic. In borax, O. F. the *amethyst-red bead for manganese.* Dissolves in heated HCl *with evolution of carbon dioxide.* Occurs in ore veins of the heavy metals.

Zaratite, $(NiOH)_2CO_3.Ni(OH)_2.4H_2O$. Amorphous. Color bright emerald green, in *glassy crusts.* Heated B. B. blackens, and in R. F. becomes gray, magnetic. Gives a reaction for *nickel* in the borax bead. In the closed tube gives *water.* Soluble in heated HCl with evolution of CO_2. Occurs with chromite and serpentine. Rare.

Aurichalcite, a basic carbonate of copper and zinc, would belong here. Rare.

Compare *Uraninite* under *metallic luster*, which sometimes looks rather dull and which, when dissolved in acid, evolves a little gas (helium or argon). Compare also Wad, below.

b. Fused in a closed tube with soda and metallic magnesium, and the resulting mass placed in water evolve *phosphine*, indicating a *phosphate.*

APATITE, $Ca_5(Cl,F)(PO_4)_3$, III. Generally green, blue or colorless, also colored by mechanical impurities. Heated B. B. the mineral becomes rounded upon the thin edges, fusing slightly, and hence coming in the fusible division in some cases. Generally gives slight *reactions for chlorine* and *fluorine.* In the nearly neutral

PART III.*

PHYSICAL DETERMINATIVE MINERALOGY.

Tables for the Determination of Minerals by Physical Properties.

BY AMOS P. BROWN.

In the following analytical key the minerals are arranged in such a manner that a few observations and tests will immediately narrow down the possibilities to a few species in a small group. Instead of basing the classification upon one set of physical properties alone, all of the physical properties have been taken advantage of, and it is hoped that this will result in facilitating the work of determination. No simple method for determining the relative hardness of minerals with exactness has yet been devised, laboratory sclerometers not being applicable to such determinative work as is here intended; so that hardness is given upon the scale of Mohs, which is as follows:

1. Talc.
2. Gypsum.
3. Calcite.
4. Fluorite.
5. Apatite.
6. Orthoclase.
7. Quartz.
8. Topaz.
9. Sapphire corundum.
10. Diamond.

For these test pieces, crystals should be used as far as

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or submetallic luster. Earthy. In closed tube gives water. Soluble in HCl with evolution of chlorine. A manganese ore, called also *bog manganese.*

ZINCITE. ZnO, III. Hemimorphic, contains Mn isomorphous with Zn. Scarlet, ruby red, orange red, *streak orange.* Heated B. B. in R. F., best with a little soda and charcoal, gives on strong ignition a white coating of zinc oxide; which, when treated with cobalt nitrate and again ignited, assumes a *fine green color* on cooling. An important zinc ore at the Franklin, N. J., mines.

d. In the borax bead in O. F. a reddish-brown color when hot, becoming pale yellow when cold, and in R. F. an olive green or bottle green indicating *iron.*

HEMATITE, Fe_2O_3, III R. Often compact or earthy. Color generally red, streak red; quietly soluble in strong hydrochloric acid; the solution gives a red-brown precipitate with ammonia. Gives *no water* in the closed tube. Heated B. B. fuses at about 5 or is infusible; in R. F. becomes strongly magnetic. The most important ore of iron.

TURGITE, *Hydrohematite*, $Fe_4O_5(OH)_2$ compact fibrous. Heated B. B. in closed tube *decrepitates strongly*, and splinters to pieces, giving *some water.* Otherwise its reactions and appearance resemble those of hematite including the *red streak.* An iron ore.

LIMONITE, $Fe_4O_3(OH)_6$, IV. Compact fibrous, also earthy. Color shades of brown, *streak brownish ochre* color. Yields *much water* in the closed tube. Other reactions same as for hematite. *Brown Hematite* iron ore, an important ore.

GOETHITE, FeO(OH), IV. Compact radiating fibers.

Color shades of brown, generally lighter than limonite, also reddish brown. Sometimes fine scaly. *Streak ochre yellow.* In its reactions goethite resembles hematite, except that it yields *much water* in a closed tube. An iron ore.

c. On charcoal reduced to *antimony*, giving a copious white coating on the charcoal.

Cervantite, $SbSbO_4$, IV. In acicular crystals, massive, earthy. Pale ochre color to white. With difficulty soluble in HCl. Reacts for antimony only. With antimony ores, not common.

Division 5.—Form a jelly with hydrochloric acid or are decomposed with the separation of silica, but without gelatinizing; and do not give the reactions of the preceding divisions.

Section i.—In the closed tube give water.

a. In the borax bead in O. F. green when hot, blue when cold, and in R. F. red, opaque, indicating *copper*.

Dioptase, H_2CuSiO_4, III R., and CHRYSOCOLLA, $H_2CuSiO_4H_2O$ amorphous. Dioptase is transparent, emerald-green, in crystals resembling quartz crystals in form. Rare. *Chrysocolla* is bluish-green, even blue, glassy to opaque and amorphous; it does not gelatinize with acids, but is decomposed; *dioptase* on the other hand forms a jelly with acids. In the closed tube both give much water and become black. Surface ores of copper, produced by alteration of the sulphides.

b. In the borax bead in O. F. purple when hot, brown when cold and in the strongly saturated bead easily reduced to gray metal with a hot reducing flame, indicating *nickel*.

GARNIERITE, $H_2(Ni,Mg)SiO_4$, and *Genthite*, $H_4(NiMg)_2Si_3O_{10}$, amorphous. Color pale to bright apple green,

luster dull, generally adhere to the tongue. B. B. blacken, but do not fuse; in closed tube give water. Decomposed by HCl without gelatinizing. Important nickel ores.

c. In the borax bead O. F. red-brown when hot, paling on cooling to yellow or colorless, in R. F. olive to bottle-green, indicating *iron.*

Chloropal, $H_4Fe_2Si_2O_9$. Compact. In the blowpipe flame blackens and in R. F. becomes magnetic. Partially decomposed by HCl, the silica remaining insoluble. Closely allied is *pinguite*, which is decomposed completely with HCl, with separation of silica. Not common. With iron ores. Compare also *serpentine* which may give an iron reaction with borax.

d. In borax bead in O. F. reddish-brown when hot, yellow-green when cold, becoming on reduction fine emerald-green, indicating *chromium.*

Wolchonskoite, a clay-like silicate containing Fe, Cr, Al, amorphous. Color bluish-green, streak somewhat paler, shining. Soft. Heated B. B. blackens and is infusible, in R. F. becomes somewhat magnetic. In the closed tube gives water. Gelatinizes with hot concentrated HCl. Rare.

e. In a salt of phosphorus bead a yellow-green color in O. F. which becomes fine emerald-green in R. F., indicating *uranium.*

Uranophane, $CaU_2Si_2O_{11}.5H_2O$. Lemon-yellow, straw-yellow. B. B. becomes dark, in a closed tube much water. Soluble in HCl, the silica separating, flocculent, Rare.

f. *Not* included under the foregoing heads.

SERPENTINE, $H_4(Mg,Fe)_3Si_2O_9$. Generally compact

massive. Color various shades of green, brownish, red, yellow, also gray. Heated B. B. rounds upon thin edges or is infusible. Darkens when heated in a closed tube, and gives off water. Concentrated HCl slowly decomposes it with separation of silica. Sulphuric acid decomposes it rather more readily. In this solution, oxidized with a few drops of HNO_3, ammonia generally precipitates a little iron, and, in the filtrate from this precipitation, salt of phosphorus gives a copious precipitate of magnesium-ammonium phosphate. Varieties of serpentine based upon physical characters are distinguished; the fibrous form is called *chrysotile*, this is the ordinary *asbestus* of commerce; *antigorite* is a lamellar form of serpentine.

Sepiolite is near serpentine in composition; it is generally found to be fusible, but with difficulty. B. B. it whitens and shrinks together. Adheres to the tongue. See Class II, Part B, Div. 4, Sec. i, b, for serpentines, sepiolite, etc. *Deweylite* is also near serpentine; it resembles a gum in appearance.

Seybertite, *Clintonite*, $H_3(Mg,Ca,Fe)_5Al_5Si_2O_{18}$, V. Colors brown, reddish, luster pearly to submetallic. B. B. infusible, but becomes lighter in color. Decomposed by acids with separation of silica. Not very common. Harder than common micas and more brittle.

Cerite, $(Ca,Fe)(CeO)Ce_2(OH)_3(SiO_3)_3$, IV. Usually massive, color gray, pinkish-gray, blackish. B. B. infusible, but with borax gives a yellow bead (iron). Does not form a clear glass with sodium carbonate, but becomes yellow, opaque. With HCl forms a jelly upon evaporation. In the solution, from which silica has been separated, oxalic acid produces a white precipitate; it

this is now dried and ignited it assumes a *brick red color* (cerium oxides). Used for incandescent gas lights.

CHONDRODITE, $[Mg(FOH)]_2Mg_3(SiO_4)_2$, V. Color honey-yellow, brownish, generally in rounded grains. In a closed tube a little water on intense ignition. With fused salt of phosphorus in a closed tube a *fluorine* reaction. With borax in O. F. generally an iron reaction. *Gelatinizes* with HCl on evaporation. Closely related are *Humite* and *Clinohumite;* unless good crystals are obtainable they must be distinguished by quantitative analysis. They occur in metamorphic limestones.

Section ii.—In the closed tube give no water.

a. Gelatinize with hydrochloric acid.

CHRYSOLITE, $(Mg,Fe)_2SiO_4$, IV. Pale green to dark olive-green. Infusible B. B. With hydrochloric acid *gelatinizes very readily;* in the filtrate from this solution, from which the silica has been separated (by evaporation to dryness, taking up in HCl and adding a drop of HNO_3), ammonia gives a slight precipitate of *ferric hydrate.* If this is separated, ammonium oxalate gives no precipitate in the filtrate (absence of calcium); but salt of phosphorus gives a copious precipitate (*magnesium*). *Forsterite* is a chrysolite without iron. Compare *Hortonolite, Roepperite.* Chrysolite is an important rock-forming mineral in basic igneous rocks. Used sometimes as a gem.

Gadolinite, $Fe[Be(YO)SiO_4]_2$, V. Black, vitreous, resembling a black glass. Translucent on thin edges with an olive-green color. Heated B. B. *swells and glows*, often cracks or splits but does not fuse to a *globule*, *generally whitens* or becomes paler when heated. Gela-

inizes with HCl. In the borax bead an iron reaction. Contains Yttrium, see under *Reactions of the Elements;* p. 202. Rare.

WILLEMITE, Zn_2SiO_4, III R; generally gives the green zinc reaction with cobalt nitrate or blue with same reagent, and will hence be found in the preceding divisions. *Gelatinizes very readily.* With a little soda and charcoal dust on charcoal a *zinc* coating, which is yellow when hot and white on cooling, and when treated with cobalt nitrate and again ignited it assumes a *fine green color* when cold.

b. Decomposed with hydrochloric acid *without gelatinizing.*

LEUCITE, $KAlSi_2O_6$, I. In trapezohedrons. Colorless, gray, yellowish; when broken, vitreous, often dull on the crystal surfaces. Heated B. B. remains unchanged, but with cobalt nitrate generally assumes a blue color. Decomposed by HCl *without gelatinizing.* In certain basalts and lavas, a rock-forming mineral. Easily recognized by its form, which resembles that of garnet.

Division 6.—Insoluble in hydrochloric acid or but slightly attacked.

Section i. Hardness not above 4.5, can be scratched by a wire nail.

a. Give *water* in a closed tube.

The minerals under this head are mainly *micaceous* in texture. Compare the *elastic micas* in Class II, Pt. B, Div. 4, Sec. ii, e. p. 283, which fuse just below or about 5. Compare also *Talc.*

CLINOCHLORE, PENNINITE, CHLORITE MICAS. *Non-elastic but tough,* see p. 284, as above. These micas are *Mg and Al silicates,* with a composition of about

$H_{20}Mg_{12}Al_6Si_7O_{45}$, V, characterized by a *green or blue-green color*. Give *much water* in closed tube, mainly given off at a high temperature. Heated B. B. become pearly and fuse with much difficulty (generally above 5) to a black glass. React for iron in the borax bead. *Completely decomposed by boiling* H_2SO_4. Rock-making mineral in schists, etc., from metamorphosed igneous rocks.

Genthite or *garnierite* is decomposed by HCl with some difficulty and might be placed under this head. Compare also *Bauxite*, Division 1, d., p. 291.

b. Give *no water* in the closed tube.

Xenotime, $(Y,Ce,Er)PO_4$, II. Grayish or yellowish-brown. Infusible and unaltered B. B. In a bead of salt of phosphorus, dissolves slowly and with difficulty to a clear bead. Not affected by hydrochloric but decomposed by concentrated sulphuric acid. In this solution, diluted, the addition of an oxalate causes a precipitate of the rare earth metals, white. On ignition this precipitate becomes rusty colored. Xenotime occurs in granite and gneiss. Rare.

Compare also cervantite, SbO_2, which dissolves in HCl with difficulty; see Div. 4, e, above.

Section ii. Hardness above 4.5 but not above 7, can be scratched by a piece of quartz (7).

a. Gives *water* in a closed tube.

Opal, $nSiO_2.H_2O$, amorphous. Infusible, generally whitens when heated B. B. In a closed tube on intense ignition gives water. Fused in a bead of sodium carbonate dissolves with *strong effervescence*. Mostly soluble *in solution of* caustic potash. The varieties of opal that *show a play* of color are prized as a gem; they are dis-

tinguished as *fire opal* when there is a red reflection; the ordinary *precious opals* show generally blue and green colors. *Common opal* shows no play of colors but may be colored by mechanical impurity. The clear glassy opal is called *Hyalite.* In more massive form or making considerable deposits, opal occurs as *opalized wood, silicious sinter, diatomaceous earth, Tripoli* and other varieties. Precious opal is generally procured from altered igneous rocks.

Compare *Seybertite,* Div. 5, Sec. i, f. p. 279.

b. Fused with borax or sodium carbonate and the resulting mass dissolved in HCl and boiled with tin, the liquid assumes a violet or purplish color not changing to a blue on further boiling. *Titanium.*

RUTILE, TiO_2, II. In prismatic crystals, *vertically striated, twinned, often repeatedly.* Color reddish, brownish to nearly black; by transmitted light ruby-red; rarely greenish. Luster adamantine to almost submetallic. Generally contains enough iron to give a reaction in the borax bead. With salt of phosphorus in R. F. the strongly saturated bead is *purplish-violet.* When pure used for coloring artificial teeth.

Octahedrite, TiO_2, II. Black or brown, yellow, sometimes fine blue. In pyramidal crystals, sometimes with the square prism, *horizontally striated.* Reactions as for rutile.

BROOKITE, TiO_2, IV. Brown to black, crystals often tabular, *generally distinctly orthorhombic,* always readily distinguished from tetragonal. Reactions same as for rutile.

Perovskite, $CaTiO_3$, I. Colors pale yellowish, honey to *orange-yellow,* brownish, gray, also nearly black. *Heated B. B. infusible.* With salt of phosphorus dis-

luster dull, generally adhere to the tongue. B. B. blacken, but do not fuse; in closed tube give water. Decomposed by HCl without gelatinizing. Important nickel ores.

c. In the borax bead O. F. red-brown when hot, paling on cooling to yellow or colorless, in R. F. olive to bottle-green, indicating *iron.*

Chloropal, $H_4Fe_2Si_2O_9$. Compact. In the blowpipe flame blackens and in R. F. becomes magnetic. Partially decomposed by HCl, the silica remaining insoluble. Closely allied is *pinguite*, which is decomposed completely with HCl, with separation of silica. Not common. With iron ores. Compare also *serpentine* which may give an iron reaction with borax.

d. In borax bead in O. F. reddish-brown when hot, yellow-green when cold, becoming on reduction fine emerald-green, indicating *chromium.*

Wolchonskoite, a clay-like silicate containing Fe, Cr, Al, amorphous. Color bluish-green, streak somewhat paler, shining. Soft. Heated B. B. blackens and is infusible, in R. F. becomes somewhat magnetic. In the closed tube gives water. Gelatinizes with hot concentrated HCl. Rare.

e. In a salt of phosphorus bead a yellow-green color in O. F. which becomes fine emerald-green in R. F., indicating *uranium.*

Uranophane, $CaU_2Si_2O_{11}.5H_2O$. Lemon-yellow, straw-yellow. B. B. becomes dark, in a closed tube much water. Soluble in HCl, the silica separating, flocculent, Rare.

f. Not included under the foregoing heads.

SERPENTINE, $H_4(Mg,Fe)_3Si_2O_9$. Generally compact,

A. MINERALS WITH METALLIC LUSTER, i. e., HAVING THE APPEARANCE OF A METAL.

I. Malleable, will flatten under a hammer or may be cut into shavings with a knife.

1. Hardness under 2.5, can be scratched with the finger-nail.

a. Color white.

MERCURY, Hg. Liquid above —40 C.; G. = 13.6. Color tin-white; occurs disseminated in scattered globules through the gangue; generally associated with cinnabar HgS.

TIN, Sn. in grains. H = 2; G = 6.5–7.1. Color tin-white. Has been reported from New South Wales and a few other localities only.

BISMUTH, Bi, III R. H = 2–2.5; G = 9.7–9.8. Color tin-white with a reddish tinge. Scarcely malleable to brittle. Cleavage (0001) perfect. An ore of bismuth.

b. Color lead to steel-gray.

MOLYBDENITE, MoS_2, III. H = 1–1.5; G = 4.7–4.8. Color lead-gray with a bluish tinge. Cleavage basal, perfect; cleavage laminæ flexible, rather tough. Streak gray, slightly greenish; rubbed streak, greenish. Distinguished from graphite by its bluish color. Occurs in granite, etc. The principal source of molybdic acid, MoO_3.

LEAD, Pb., I. H = 1.5; G = 11.37. Color lead-gray, very malleable and ductile. Occurs in thin plates or globules. Rare.

c. Color iron-gray.

GRAPHITE, C., III. H = 1.2; G = 2.1–2.2. Color *iron-gray. Streak* and rubbed streak gray. Occurs in

this is now dried and ignited it assumes a *brick red color* (cerium oxides). Used for incandescent gas lights.

CHONDRODITE, $[Mg(FOH)]_2Mg_3(SiO_4)_2$, V. Color honey-yellow, brownish, generally in rounded grains. In a closed tube a little water on intense ignition. With fused salt of phosphorus in a closed tube a *fluorine* reaction. With borax in O. F. generally an iron reaction. *Gelatinizes* with HCl on evaporation. Closely related are *Humite* and *Clinohumite;* unless good crystals are obtainable they must be distinguished by quantitative analysis. They occur in metamorphic limestones.

Section ii.—In the closed tube give no water.

a. Gelatinize with hydrochloric acid.

CHRYSOLITE, $(Mg,Fe)_2SiO_4$, IV. Pale green to dark olive-green. Infusible B. B. With hydrochloric acid *gelatinizes very readily;* in the filtrate from this solution, from which the silica has been separated (by evaporation to dryness, taking up in HCl and adding a drop of HNO_3), ammonia gives a slight precipitate of *ferric hydrate.* If this is separated, ammonium oxalate gives no precipitate in the filtrate (absence of calcium); but salt of phosphorus gives a copious precipitate (*magnesium*). *Forsterite* is a chrysolite without iron. Compare *Hortonolite, Roepperite.* Chrysolite is an important rock-forming mineral in basic igneous rocks. Used sometimes as a gem.

Gadolinite, $Fe[Be(YO)SiO_4]_2$, V. Black, vitreous, resembling a black glass. Translucent on thin edges with an olive-green color. Heated B. B. *swells and glows,* often cracks or splits but does not fuse to a *globule,* generally whitens or becomes paler when heated. Gela-

tinizes with HCl. In the borax bead an iron reaction. Contains Yttrium, see under *Reactions of the Elements;* p. 202. Rare.

WILLEMITE, Zn_2SiO_4, III R; generally gives the green zinc reaction with cobalt nitrate or blue with same reagent, and will hence be found in the preceding divisions. *Gelatinizes very readily.* With a little soda and charcoal dust on charcoal a *zinc* coating, which is yellow when hot and white on cooling, and when treated with cobalt nitrate and again ignited it assumes a *fine green color* when cold.

b. Decomposed with hydrochloric acid *without gelatinizing.*

LEUCITE, $KAlSi_2O_6$, I. In trapezohedrons. Colorless, gray, yellowish; when broken, vitreous, often dull on the crystal surfaces. Heated B. B. remains unchanged, but with cobalt nitrate generally assumes a blue color. Decomposed by HCl *without gelatinizing.* In certain basalts and lavas, a rock-forming mineral. Easily recognized by its form, which resembles that of garnet.

Division 6.—Insoluble in hydrochloric acid or but slightly attacked.

Section i. Hardness not above 4.5, can be scratched by a wire nail.

a. Give *water* in a closed tube.

The minerals under this head are mainly *micaceous* in texture. Compare the *elastic micas* in Class II, Pt. B, Div. 4, Sec. ii, e. p. 283, which fuse just below or about 5. Compare also *Talc.*

CLINOCHLORE, PENNINITE, CHLORITE MICAS. *Non-elastic but tough,* see p. 284, as above. These micas are *Mg and Al silicates,* with a composition of about

luster dull, generally adhere to the tongue. B. B. blacken, but do not fuse; in closed tube give water. Decomposed by HCl without gelatinizing. Important nickel ores.

c. In the borax bead O. F. red-brown when hot, paling on cooling to yellow or colorless, in R. F. olive to bottle-green, indicating *iron.*

Chloropal, $H_4Fe_2Si_2O_9$. Compact. In the blowpipe flame blackens and in R. F. becomes magnetic. Partially decomposed by HCl, the silica remaining insoluble. Closely allied is *pinguite*, which is decomposed completely with HCl, with separation of silica. Not common. With iron ores. Compare also *serpentine* which may give an iron reaction with borax.

d. In borax bead in O. F. reddish-brown when hot, yellow-green when cold, becoming on reduction fine emerald-green, indicating *chromium.*

Wolchonskoite, a clay-like silicate containing Fe, Cr, Al, amorphous. Color bluish-green, streak somewhat paler, shining. Soft. Heated B. B. blackens and is infusible, in R. F. becomes somewhat magnetic. In the closed tube gives water. Gelatinizes with hot concentrated HCl. Rare.

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f. Not included under the foregoing heads.

Serpentine, $H_4(Mg,Fe)_3Si_2O_9$. Generally compact,

massive. Color various shades of green, brownish, red, yellow, also gray. Heated B. B. rounds upon thin edges or is infusible. Darkens when heated in a closed tube, and gives off water. Concentrated HCl slowly decomposes it with separation of silica. Sulphuric acid decomposes it rather more readily. In this solution, oxidized with a few drops of HNO_3, ammonia generally precipitates a little iron, and, in the filtrate from this precipitation, salt of phosphorus gives a copious precipitate of magnesium-ammonium phosphate. Varieties of serpentine based upon physical characters are distinguished; the fibrous form is called *chrysotile*, this is the ordinary *asbestus* of commerce; *antigorite* is a lamellar form of serpentine.

Sepiolite is near serpentine in composition; it is generally found to be fusible, but with difficulty. B. B. it whitens and shrinks together. Adheres to the tongue. See Class II, Part B, Div. 4, Sec. i, b, for serpentines, sepiolite, etc. *Deweylite* is also near serpentine; it resembles a gum in appearance.

Seybertite, *Clintonite*, $H_8(Mg,Ca,Fe)_5Al_5Si_2O_{18}$, V. Colors brown, reddish, luster pearly to submetallic. B. B. infusible, but becomes lighter in color. Decomposed by acids with separation of silica. Not very common. Harder than common micas and more brittle.

Cerite, $(Ca,Fe)(CeO)Ce_2(OH)_3(SiO_3)_3$, IV. Usually massive, color gray, pinkish-gray, blackish. B. B. infusible, but with borax gives a yellow bead (iron). Does not form a clear glass with sodium carbonate, but becomes yellow, opaque. With HCl forms a jelly upon evaporation. In the solution, from which silica has been separated, oxalic acid produces a white precipitate; it

this is now dried and ignited it assumes a *brick red color* (cerium oxides). Used for incandescent gas lights.

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b. Decomposed with hydrochloric acid *without gelatinizing.*

LEUCITE, $KAlSi_2O_6$, I. In trapezohedrons. Colorless, gray, yellowish; when broken, vitreous, often dull on the crystal surfaces. Heated B. B. remains unchanged, but with cobalt nitrate generally assumes a blue color. Decomposed by HCl *without gelatinizing.* In certain basalts and lavas, a rock-forming mineral. Easily recognized by its form, which resembles that of garnet.

Division 6.—Insoluble in hydrochloric acid or but slightly attacked.

Section i. Hardness not above 4.5, can be scratched by a wire nail.

a. Give *water* in a closed tube.

The minerals under this head are mainly *micaceous* in texture. Compare the *elastic micas* in Class II, Pt. B, Div. 4, Sec. ii, e. p. 283, which fuse just below or about 5. Compare also *Talc.*

CLINOCHLORE, PENNINITE, CHLORITE MICAS. *Non-elastic but tough,* see p. 284, as above. These micas are *Mg and Al silicates,* with a composition of about

B. Minerals with sub-metallic and non-metallic luster and black or colored streak.
   I. Streak black, p. 333.
   II. Streak brown, p. 334.
   III. Streak red, p. 338.
   IV. Streak yellow or brownish yellow, p. 341.
   V. Streak green, p. 345.
   VI. Streak blue, p. 349.

C. Minerals with uncolored or gray streak.
   I. Hardness under 2.5, may be scratched with the finger-nail, p. 351.
   II. Hardness 2.5 to 4.5, cannot be scratched with the finger-nail but may be scratched with a wire nail, p. 359.
   III. Hardness 4.5 to 6, cannot be scratched by a wire nail but may be scratched by a knife, p. 368.
   IV. Hardness 6 to 7, not scratched by a knife, but scratched by quartz (perhaps with difficulty), p. 376.
   V. Hardness 7.5 to 10. Easily scratch quartz, p. 385.

A. MINERALS WITH METALLIC LUSTER, i. e., HAVING THE APPEARANCE OF A METAL.

I. Malleable, will flatten under a hammer or may be cut into shavings with a knife.

1. Hardness under 2.5, can be scratched with the finger-nail.

a. Color white.

MERCURY, Hg. Liquid above —40 C.; G. = 13.6. Color tin-white; occurs disseminated in scattered globules through the gangue; generally associated with cinnabar HgS.

TIN, Sn. in grains. H = 2; G = 6.5–7.1. Color tin-white. Has been reported from New South Wales and a few other localities only.

BISMUTH, Bi, III R. H = 2–2.5; G = 9.7–9.8. Color tin-white with a reddish tinge. Scarcely malleable to brittle. Cleavage (0001) perfect. An ore of bismuth.

b. Color lead to steel-gray.

MOLYBDENITE, MoS_2, III. H = 1–1.5; G = 4.7–4.8. Color lead-gray with a bluish tinge. Cleavage basal, perfect; cleavage laminæ flexible, rather tough. Streak gray, slightly greenish; rubbed streak, greenish. Distinguished from graphite by its bluish color. Occurs in granite, etc. The principal source of molybdic acid, MoO_3.

LEAD, Pb., I. H = 1.5; G = 11.37. Color lead-gray, very malleable and ductile. Occurs in thin plates or globules. Rare.

c. Color iron-gray.

GRAPHITE, C., III. H = 1.2; G = 2.1–2.2. Color *iron-gray. Streak* and rubbed streak gray. Occurs in

flat, six-sided plates or scales, also foliated-massive and compact, somewhat brittle. Found in granites and in metamorphic rocks, also in crystalline limestones. Used for lubrication, pencils, crucibles, etc.

ARGENTITE, Ag_2S, I. H = 2–2.5; G = 7.2–7.36. Color iron-gray, tarnishing dead-black on exposure. Streak black; rubbed streak becomes yellowish. Somewhat tough. Commonly in cubes, octahedrons, etc., or in irregular forms through the gangue, which is generally quartz, but the veins of the ore are often in limestone. An important silver ore.

HESSITE, Ag_2Te, I, and PETZITE $(Ag,Au)_2Te$, massive, resemble argentite, but are slightly harder, scarcely yielding to the finger-nail. They do not tarnish so readily as argentite. Silver and gold ores.

2. Hardness 2.5 or above, cannot be scratched with the finger-nail.

a. Color white.

SILVER, Ag, I. H = 2.5–3; G = 10.1–11.1. Color silver-white, tarnishing. In arborescent groups of crystals, or like wire, foil, etc. Ductile and malleable.

AMALGAM, (Ag,Hg), 1. H = 3–3.5; G = 13.75–14.1. Color silver-white, does not readily tarnish. Malleable to brittle; not ductile. Rare.

IRIDOSMINE, (Ir,Os), III R. Hard, H = 6–7; G = 19.3–21.1. Somewhat malleable. Color tin-white, inclining slightly to bluish. Occurs in grains in sands like gold or platinum; as from California.

b. Color iron-gray.

PLATINUM, (Pt,Fe) I. H = 4–4.2; G = 14–19. Color *steel-gray to* iron-gray. Sometimes magnetic; malleable.

and ductile. Occurs in grains, rarely in crystals, in sands, etc.

IRON, Fe, I. H = 4.5; G = 7.3–7.8. Magnetic. Rusted when exposed. Generally shows cleavage parallel to the octahedron. Terrestrial or meteoric, rare.

c. Color yellow, red, etc.

GOLD, Au, I. H = 2.5–3; G = 15.5–19.3. Color varies as the alloy is with silver or copper; generally gold yellow; streak gold yellow, rubbed streak purplish gray. Placer gold is in grains or nuggets rounded by water. Vein gold is in strings or arborescent shapes. Very malleable and ductile.

ELECTRUM, (Au,Ag) I. H = 2.5–3; G = 12.4–15.5 Color pale yellow to nearly white. Habit same as gold. With gold ores.

COPPER, Cu, I. H = 2.5–3; G = 8.8–8.9. Common crystals are cube and dodecahedron. Twins, and grows in arborescent forms; also massive, in sheets, strings, etc., through the gangue. Color copper red; streak same; rubbed streak greenish. Much commercial copper is produced from the native metal.

A. II. Brittle, powders under the hammer or knife point.

1. Hardness under 2.5, can be scratched with the finger-nail.

a. Color white.

BISMUTH, Bi, III R. H = 2–2.5; G = 9.7–9.8. Color reddish tin white; brittle, to slightly malleable, Cleavage basal, perfect.

TELLURIUM, Te, III R. Commonly massive. H=2–2.5; *G = 6.2.* *Tin* white in color, tarnishing dull. *Brittle.*

b. Color lead gray to steel gray.

Tetradymite, $Bi_2(TeS)_3$, III R. H=1.5–2; G=7.2–7.6. Marks paper. Color pale steel gray. Cleavage basal, perfect, making the mineral micaceous in appearance. Occurs with gold ores.

SYLVANITE $(Au,Ag)Te_2$, V. H=1.5–2; G=7.9–8.3. Color steel gray, sometimes yellowish; streak gray, rubbed streak brownish. By twinning the mineral becomes arborescent or occurs in forms resembling written characters, hence the name "graphic tellurium."

Krennerite closely resembles Sylvanite but is orthorhombic.

Nagyagite, $Au_2Pb_{14}Sb_8(S,Te)_{24}$, IV. H=1–1.5; G=6.8–7.2. Color dark lead gray; streak gray, on rubbing yellowish-brown; crystals tabular, or in foliated masses. Thin laminæ flexible. These are the principal "Telluride" gold ores.

STIBNITE, Sb_2S_3, IV. H=2; G=4.5. Color lead gray; streak blackish lead gray; rubbed streak is orange-brown. Cleavage (010) perfect; cross striations due to gliding planes parallel (001). Crystals often striated parallel to the length. Also fibrous to stalky, massive. The principal antimony ore.

Bismuthinite, Bi_2S_3, IV. H=2; G=6.4–6.5. Color light lead gray; streak gray, rubbed streak reddish-brown. In needle-like crystals or fibrous massive. Occurs with metallic bismuth.

Freieslebenite, $(Pb,Ag_2)_5Sb_4S_{11}$, V. H=2–2.5; G=6.2–6.4. Color and streak light steel gray. Crystals prismatic, striated; fracture subconchoidal. Also massive, granular.

Berthierite, $FeSb_2S_4$. Fibrous massive. H=2–3; G=4–4.3. Color dark steel gray, tarnishing brownish and steel blue; streak black, rubbed streak yellowish-black; otherwise resembles Stibnite but is harder.

JAMESONITE, $Pb_2Sb_2S_5$, IV. Generally fibrous massive. H=2–3; G=5.5–5.8. Color lead gray; rubbed streak yellowish brown; does not tarnish. The fibers are finer than those of Berthierite or Stibnite.

c. Color iron gray.

STEPHANITE, Ag_5SbS_4, IV. H=2–2.5; G=6.2–6.3. Color iron gray, does not tarnish. Streak iron gray; rubbed streak brownish. Very brittle, called brittle silver ore. Occurs disseminated through the gangue or in crystals in cavities and fissures. An important ore.

Polybasite, Ag_9SbS_6, IV. H=2–3; G=6–6.2. Color dark iron-gray; streak black; rubbed streak, brownish. Closely resembles the last. A silver ore.

PYROLUSITE, MnO_2, IV. H=2–2.5; G=4.73–4.86. Color iron-gray; streak black, when rubbed becoming brownish-gray. In prisms, striated in the direction of the length, also fibrous massive, and earthy or compact. Generally marks paper. Manganese ore, also used for evolving chlorine in bleaching.

Hessite (see under malleable. Hessite is only slightly malleable).

Miargyrite, $AgSbS_2$, V. H = 2–2.5; G = 5.1–5.3. Color iron-gray; streak cherry-red. Generally massive, crystals much modified. Rare.

d. Color bronzy.

Sternbergite, $AgFe_2S_3$, IV. H = 1–1.5; G = 4.1–4.2. Color pinchbeck-bronze with sometimes a violet tarnish. Streak black, marks paper. In tabular crystals with *strong basal cleavage.* Thin laminæ flexible. Rare.

2. Hardness 2.5 or above, but under 4.5. Cannot be scratched with the finger-nail, but can be scratched with a wire nail.

a. Color white.

ANTIMONY, Sb, III R. H = 3–3.5; G=6.65–6.72. Color and streak tin white; not readily tarnishing; granular massive, with strong basal cleavage; sometimes fine granular to compact. Very brittle, easily powdered. Occurs with Stibnite; an antimony ore.

Arsenic, As, III R. H = 3.5; G = 5.6–5.7. Color and streak tin white, tarnishing quickly to dull dark gray. Generally granular, massive or in reniform crusts. Fracture fine granular to compact. Not important as a source of arsenic.

Allemontite, (As,Sb), III R. H = 3.5; G = 6.2. Color tin-white, tarnishing to dull gray or brownish. Massive granular to compact, often reniform and lamellar.

Amalgam. (See under malleable. Amalgam is sometimes brittle).

DYSCRASITE, Ag_3Sb, IV. H = 3.5–4; G = 9.4–9.8. Color and streak silver-white, sometimes tarnishing darker. In crystals and massive granular. The very high specific gravity serves to distinguish this mineral. A silver ore.

b. Color lead gray to steel gray.

Tiemannite, HgSe, I, tetrahedral. H = 2.5; G = 8.19–8.47. Color dark lead-gray; streak black, rubbed streak olive-brown. Commonly massive granular, to compact; fracture uneven. Rare.

Galenite, PbS, I. H = 2.5–2.75; G=7.4–7.6. Color and streak lead gray; rubbed streak yellowish-brown

does not tarnish. Cleavage cubic, perfect, commonly in cubes or octahedrons, or cleavable massive to fine granular. Nearly always contains silver. The principal lead ore.

CHALCOCITE, Cu_2S, IV. H = 2.5–3; G = 5.5–5.8. Color and streak dark lead-gray (rubbed streak yellowish-gray); tarnishing bluish, then black and dull. Crystals are pseudo-hexagonal, striated; commonly massive; fracture sub-conchoidal. Often associated with a green mineral (malachite), due to weathering. An important copper ore.

Bournonite $(PbCu_2)_3Sb_2S_6$, IV. H = 2.5–3; G = 5.7–5.9. Color and streak dark steel-gray, sometimes tarnishing blue, purple, green to black; rubbed streak reddish-brown. In tabular crystals and massive compact; fracture sub-conchoidal, smooth. Rather rare.

Boulangerite, $Pb_5Sb_4S_{11}$, IV. H = 2.5–3; G = 5.75–6. Color lead-gray, somewhat bluish. Rubbed streak red-brown. Commonly fibrous massive, also compact granular. Rather rare.

STANNITE, Cu_2FeSnS_4, I, tetrahedral. H = 4; G = 4.3–4.5. Color steel-gray, but generally yellowish or greenish, due to chalcopyrite admixture. Massive granular; streak nearly black; rubbed streak brownish-gray. An ore of tin in the Cornish mines.

c. Color iron-gray.

Stromeyerite $(Cu,Ag)_2S$, IV. H=2.5–3; G=6.2–6.3. Color and streak iron-gray (rubbed streak somewhat brownish-gray), tarnishing bluish and black, like chalcocite. Somewhat sectile, not so brittle as chalcocite. A silver and copper ore.

TETRAHEDRITE, $(Cu_2Ag_2,Fe,Zn)_4(As,Sb)_2S_7$, I, tetra-

hedral. H = 3–4; G = 4.5–5.1. Color dark iron-gray, often with a bronzy tinge, tarnishing but slightly; streak iron black to reddish-black, rubbed streak reddish-brown. In tetrahedrons, etc., or more commonly massive; fracture sub-conchoidal to uneven. Generally contains silver, also often iron, zinc, mercury. The arsenical variety is called *Tennantite*. A silver-copper ore.

d. Color bronze-yellow, bronze-brown.

Calaverite, (Au, Ag)Te_2, massive. H = 2.5; G = 9. Color pale bronze-yellow; streak yellowish-gray, metallic, rubbed streak darkens and then changes to brownish-gray. Rare, a gold ore.

Bornite, Cu_3FeS_3, I. H = 3; G = 4.9–5.4. Color pinchbeck-bronze on fresh fracture, rapidly tarnishing violet-purple, green, peacock-blue, and becoming iridescent. Streak iron-black, rubbed streak brownish-olive-green. Commonly massive; fracture small conchoidal. Often contains silver. Called *peacock-copper*, *horse-flesh ore*, etc. An important copper ore.

Pentlandite, (Fe, Ni)S, I. H = 3.5–4; G = 4.6. Color light bronze-yellow; streak bronze-brown, becoming violet on rubbing. Commonly massive; fracture uneven, granular. Differs from the next in not being magnetic. A nickel ore.

Pyrrhotite, Fe_7S_8, III. H = 3.5; G = 4.4–4.6. Color bronze-brown, tarnishing iridescent to dull; streak grayish-black, rubbed streak gray. Commonly massive; small conchoidal to uneven fracture, sometimes with laminated fracture due to basal cleavage. Magnetic, magnetism variable, occasionally showing polarity. A nickel ore when Ni replaces part of the Fe.

e, Color brass-yellow, reddish.

Whitneyite, Cu_9As. Massive. H = 3.5; G = 8.4–8.6. Color on fresh fracture reddish-white to coppery, soon tarnishing to yellowish bronze and dull brown to brownish black. Streak pale coppery, rubbed streak becomes greenish-gray. Occurs with metallic copper. Rare.

MILLERITE, NiS, III R. H = 3–3.5; G = 5.3–5.6. Color brass-yellow; streak greenish-black, shining; on rubbing becomes black then brownish gray. Commonly in capillary crystals, occurring singly, in felted masses or radiating crusts; by weathering becoming covered with a greenish-gray bloom. Often associated with Pentlandite or Pyrrhotite. A nickel ore.

CHALCOPYRITE, $CuFeS_2$, II, sphenoidal. H = 3.5–4; G = 4.2. Color deep brass-yellow, tarnishing greenish, purple, etc., iridescent, finally dull greenish-black; by weathering becoming rusty. Streak greenish-black, rubbed streak violet-black. Crystals resemble tetrahedrons and octahedrons; generally massive, fracture subconchoidal to uneven. Associated with pyrite, pyrrhotite, etc. A very important copper ore.

Cubanite, $CuFe_2S_4$, I. Massive. H = 4; G = 4.1. Color pale brass-yellow. Streak greenish, nearly black, rubbed streak violet. Resembles chalcopyrite, but is paler and not so subject to tarnish. A copper ore.

3. Hardness, 4.5 or over.

a. Color white. Isometric, mostly pyritohedral.

Linnæite, Co_3S_4, I. H = 5.5; G = 4.8–5. Color white with reddish tinge, increased by tarnish; streak grayish black, rubbed streak gray. Commonly in small octa-

hedrons, also fine granular massive. Contains nickel and iron, replacing the cobalt. Rather rare.

COBALTITE, CoAsS, I, pyritohedral. H = 5.5; G = 6–6.3. Color white with a reddish or violet tinge; streak grayish black, rubbed streak grayish brown, somewhat tinged with lilac. Crystals cube and pyritohedron; or their combination. Also granular massive. Cleavage cubic when the mineral is in crystals.

SMALTITE, $CoAs_2$, and CHLOANTHITE, $NiAs_2$, I, pyritohedral. H = 5.5–6; G = 6.4–6.6. Color silver white, more gray when massive; streak grayish black, rubbed streak pale brownish, inclining to violet brown. Crystals cubes, cubo-octahedrons, and pyritohedrons; also massive, granular. Often coated with cobalt bloom (peach blossom color) or nickel bloom (light apple green). A cobalt or nickel ore.

Sperrylite, $PtAs_2$, I, pyritohedral. H = 6–7; G = 10.6. Color silver white, streak black. In small, almost microscopic crystals, mostly cubes and cubo-octahedrons. Rare.

a a. Color white. Orthorhombic.

Löllingite, $FeAs_2$, IV. H = 5–5.5; G = 7–7.4. Color silver white, inclining to steel gray when massive; streak grayish black, rubbed streak pale brownish gray, somewhat violet. Crystals prismatic, striated; sometimes short and resembling octahedrons. Fracture uneven. Closely resembles arsenopyrite, but is whiter. Here belongs *Leucopyrite*, Fe_2As_4, massive; otherwise like Löllingite.

ARSENOPYRITE, FeAsS, IV. H = 5.5–6; G = 5.9–6.2. Color silver white to steel gray; streak grayish *black, becoming* somewhat brownish on rubbing. In

crystals like those of Löllingite; also massive, granular, columnar and compact; fracture uneven. Here also belongs *Glaucodot* (Fe,Co)AgS, like arsenopyrite. A source of As_2O_3.

b. Color lead-gray to steel-gray.

Ullmannite, NiSbS, I, pyrithohedral. H = 5.5–5; G = 6.2–6.7. Color light steel-gray; streak grayish-black, rubbed streak gray. Commonly in cubes, with cubic cleavage; also massive, cleavable or granular; fracture uneven. Color darker than Gersdorffite, cleavage more perfect.

GERSDORFFITE, NiAsS, I, pyritohedral. H = 5.5; G = 5.6–6.2. Color light steel-gray; streak grayish-black, when rubbed inclining to greenish-gray. Generally massive; in cases showing a cubical cleavage, interrupted; also granular and lamellar. Frequently coated with green nickel bloom from weathering. A nickel ore.

HEMATITE, Fe_2O_3, III R. H = 5.5–6.5; G = 4.9–5.3. Color dark steel-gray; streak cherry-red. In hexagonal plates, lamellar to granular massive; strong basal parting with striæ at 60° in many cases. This is the specular iron ore.

ARSENOPYRITE (see under *a a. White, orthorhombic*, above).

c. Color iron-gray.

HEMATITE (see above under *b*).

MAGNETITE, $FeFe_2O_4$, I. H = 5.5–6.5; G = 5.16–5.18. Color iron-gray; streak black, rubbed streak pale brownish-gray. Crystals octahedrons and dodecahe*drons, or their com*bination; parting strong, octa*hedral. Also massive* granular and lamellar or clean-

able, compact. Strongly magnetic, often shows polarity. An important iron ore.

d. Color red, yellow, etc.

Niccolite, NiAs, III. H = 5–5.5; G = 7.3–7.7. Color pale copper-red, tarnishing dull; streak nearly black, somewhat brownish, rubbed streak violet gray. Crystals very rare; commonly massive; fracture small conchoidal to uneven. Easily distinguished by its color.

MARCASITE, FeS_2, IV. H = 6–6.5; G = 4.8–4.9. Color pale brass-yellow, with a greenish tinge, color deepens on exposure, due to tarnish; streak greenish to grayish-black, rubbed streak dull olive-green. Crystals prismatic to pyramidal, twinned, often with curved faces; also massive radiating or fibrous, globular, reniform, in crusts, etc. Fracture nearly always somewhat fibrous, uneven. Very liable to oxidation in moist air, forming sulphates. Used in making sulphuric acid, etc.

PYRITE, Fe_5S_{10}, I, pyritohedral. H = 6–6.5; G = 5–5.1. Color, brass-yellow, not usually darkening or tarnishing; streak brownish-black, rubbed streak violet-brown. Commonly in cubes and pyritohedrons, also in octahedrons and combinations of these forms; fracture small conchoidal to uneven. Common in massive granular form, also globular, reniform, etc. More yellow than marcasite, not greenish. Not fibrous on the fracture. Weathers with more difficulty than marcasite to limonite and sulphuric acid. Used in making sulphuric acid. Often contains some gold.

B. MINERALS WITH SUBMETALLIC AND NON-METALLIC LUSTER AND BLACK OR COLORED STREAK.

I. Streak black. All of these minerals have a dead black streak.

1. Hardness under 2.5, can be scratched with the finger-nail.

Covellite, CuS, III. H = 1.5–2; G = 4.6. Color steel-blue, indigo-blue; submetallic luster; streak black to gray-black, shining, rubbed streak brownish-green. Crystals rare, cleavage basal, thin plates flexible. More commonly massive, sometimes pseudomorphous. Rare.

ANTHRACITE COAL. Amorphous. H = 2 2.5; G = 1.3–1.8. Color black; streak dead-black, rubbed streak brownish-black. Luster submetallic to bright. Fracture conchoidal, sometimes splintery. Does not melt nor burn, but generally decrepitates in the flame of a match. A fuel.

MELACONITE or TENORITE, CuO, V? Hardness sometimes under 2.5 in the earthy varieties. (See below under *H = 2.5 or above.*) A copper ore.

Compare also Bituminous coal, streak nearly black, see under *Brown Streak.*

2. Hardness 2.5 or above.

MELACONITE or TENORITE, CuO, V? In scales or massive. H = 3–4. G = 6. Color iron-gray to black; streak grayish-black, rubbed streak grayish olive-brown to olive-green. A copper ore.

PSILOMELANE $(Mn, Ba, K_2)_2MnO_5$. Massive. H = 5–6; *G = 3.7–4.7. Color* iron-black, bluish-black; *streak black or brownish*-black. Luster submetallic to dull.

Massive, botryoidal, stalactitic, etc., with uneven to smooth fracture. A manganese ore.

MAGNETITE, $FeFe_2O_4$, I. H = 5.5; G about 5. Color submetallic black to dead black; streak dead black, rubbed streak brownish-gray. Commonly massive when submetallic, rarely in crystals. Strongly magnetic. (See also under metallic luster A II, 3 c.)

ILVAITE, $HCaFe_2FeSi_2O_9$, IV. H = 5.5–6; G = 4. Color black, brownish-black; streak black, sometimes greenish or brownish. Crystals prismatic, vertically striated; when massive, commonly columnar, also compact. Fracture sub-conchoidal to uneven. Opaque.

Schorlomite, $Ca_3(Fe,Ti)_2[(Si,Ti)O_4]_3$, I. H = 7–7.5; G = 3.8. Color black, luster vitreous, looking like black glass. Streak pale grayish-black, rubbed streak pale reddish-brown. Sometimes crystallized, more commonly massive. Fracture conchoidal.

II. Streak brown.

1. Hardness under 2.5, can be scratched with the fingernail. All of the minerals in this division are (with one exception) compact or amorphous.

Elaterite. Hydrocarbon, amorphous. Color dark brown; streak lighter. Elastic like rubber, rarely brittle, soft. G = 0.91–1.23.

ASPHALTUM. Hydrocarbon. Amorphous, varies in hardness with the temperature, but often quite soft. G = 1–1.8. Melts very readily in match flame, burns vigorously. Harder asphaltums include *uintaite*, *gilsonite*, etc. The streak is generally deep brown; color brown to black; luster pitchy. Fracture is conchoidal to sub-conchoidal. Brittle at low temperatures. Used for paving, etc.

LIGNITE COAL. Amorphous. H = 1.5–2; G = 1.15–1.3. Color brownish-black to black; luster pitchy to dull. Streak brown. Fracture conchoidal to splintery, sometimes breaks down on weathering to angular fragments. Burns, generally without melting, in the flame of a match. A fuel.

BITUMINOUS COAL. Hydrocarbon. Amorphous. H = 0.5–2; G = 1.14–1.37. Color black and shining to dull; streak dark brown, reddish-brown. Fracture subconchoidal to splintery, often breaking into cubical fragments. Some varieties melt in the flame of a match, some do not; all burn with a bright flame. Fuels.

WAD, $MnO_2 + H_2O$, impure. Amorphous. H = 0.5–2.5; G = 3–4, but soft and feels very light. Color generally some shade of dark brown; streak umber brown. Generally soft and earthy, compact. Fracture smooth, sometimes subconchoidal. Wad contains Fe_2O_3, also often CuO, CoO, etc. A manganese ore.

Chalcophanite, $H_4(Mn,Zn)Mn_2O_7$, III R. H = 2.5; G = 3.9. Color bluish iron gray, submetallic; streak brown, dull. In scaly crystals and foliated aggregates, in crusts or cavernous massive, and drusy. Rare.

2. Hardness 2.5 to 4.5, can be scratched with a wire nail.

SPHALERITE, ZnS, I, tetrahedral. H = 3.5–4. G = 3.9–4. Color dark brown to black; luster adamantine to submetallic; streak brownish in the varieties high in iron. In crystals and massive cleavable, also rarely compact; cleavage dodecahedral, perfect. Commonly *associated with galenite*, pyrite, etc. The principal *zinc ore.*

Xenotime, YPO_4, II. H = 4–5; G = 4.45–4.55. Luster resinous; color various shades of brown; streak sometimes pale brown to yellow brown. In crystals and rolled grains accompanying monazite in granite, monazite sand, etc. Fracture uneven, sometimes splintery.

MANGANITE, MnO(OH), IV. H = 4; G = 4.2–4.4. Color iron black; submetallic; streak reddish-brown. Crystals prismatic, striated parallel to the prism; cleavage prismatic and pinacoidal; also columnar to fibrous massive. Alters to pyrolusite, etc. A manganese ore.

HUBNERITE, $MnWO_4$, V. H = 4.5–5.5; G = 6.7–7.3. In thin bladed forms; hair-brown to reddish-brown in color; streak yellowish-brown; luster metallic adamantine. Cleavage very perfect, clinopinacoidal; sometimes the mineral looks micaceous. Recognized by its high specific gravity. Hubnerite is generally harder than 4.5, see below. A tungsten ore.

3. Hardness above 4.5.

a. Fibrous to stalky.

LIMONITE, $Fe_4O_3(OH)_6$, IV, fibrous massive. H = 5–5.5; G = 3.6–4. Streak yellowish-brown; color darker brown to brownish black; luster generally dull, but bright on the reniform surfaces in some cases. Reniform, stalactitic, botryoidal, concretionary and massive; texture fibrous to earthy. An important iron ore called also *Brown Hematite*.

Hubnerite is often over 4.5 in hardness. It is fibrous to stalky. See above.

b. Compact massive.

ILMENITE or MENACCANITE, $FeTiO_3$, III R. H =

5–6; G = 4.5–5. Color iron-black, submetallic; streak brown to brownish-black. In plates imbedded in the rock, also massive lamellar and granular; often found in sands. Generally more or less magnetic. Not common in crystals. Not valuable as an iron ore.

URANINITE, UO_3, UO_2, PbO, N, etc., I. H = 5.5; G = 9–9.7. Color pitchy-black to grayish-black; streak brownish-black. Luster pitch-like to dull. Crystals rare; generally massive, compact, with a conchoidal to uneven fracture. Affects a photographic plate. Contains *Argon*, *Helium*, *Radium*, etc. Recognized by its very high specific gravity. The source of Uranium.

CHROMITE, $FeCr_2O_4$, I. In octahedrons. H = 5.5; G = 4.32–4.51. Color black, vitreous; streak brown to brownish-olive. In disseminated octahedrons in serpentine, etc.; also as crystals in sands from weathering of serpentine; massive granular to compact as ore, the common occurrence. Sometimes somewhat magnetic. The principal ore of chromium and its compounds.

Euxenite. A titano-niobate of yttrium, cerium, uranium, etc., IV. H = 6.5; G = 4.6–5. Color vitreous black, somewhat inclining to brownish; streak yellow to red-brown. Translucent in thin splinters. Affects a photographic plate. Rare.

c. Not belonging to the foregoing divisions.

Pyrochlore. Niobate of cerium, etc., I. H = 5–5.5; G = 4.2–4.36. Color brownish-black; streak light brown to yellow-brown. Luster resinous to dull. Occurs in imbedded octahedrons, in granite, etc. *Rare.*

Hausmannite, Mn_3O_4, II. H = 5–5.5; G = 4.72–

4.86. Color brownish-black, submetallic; streak chestnut-brown. In crystals resembling octahedrons, or granular massive; fracture uneven. Softer than steel. A manganese ore.

Braunite, $3Mn_2O_3.MnSiO_3$, II. H = 6–6.5; G = 4.75–4.82. Color iron-black to brownish-black, submetallic; streak brownish-black. In octahedrons, massive granular. Fracture subconchoidal to uneven. Harder than steel. Blacker streak than Hausmannite.

RUTILE, TiO_2, II. H = 6–7; G = 4.2–5.1. Color red, reddish-brown to black, submetallic adamantine; streak pale brown to nearly white. Crystals strongly striated parallel to the prism, geniculated twins common. More rarely compact massive. Used to color artificial teeth.

WOLFRAMITE, $(Fe,Mn)WO_4$, V. H = 5–5.5; G = 7.2–7.5. Color brownish-black, submetallic; streak reddish-brown, dark brown. Crystals distinctly monoclinic, cleavage (010) perfect. Massive granular, compact. The principal tungsten ore.

Compare Franklinite below, § III, p. 314, which sometimes has brown streak.

III. Streak red.

1. Hardness under 2.5, can be scratched with the finger-nail.

a. Fibrous.

Kermesite, Sb_2S_2O, V. H = 1–1.5; G = 4.5. Color purplish-red to crimson; adamantine, the tufts of fibers velvety; streak brownish-red. In tufts of capillary crystals, associated with stibnite, etc.

Erythrite, Cobalt Bloom, $Co_3As_2O_8 + 8H_2O$. H = 1.5–2.5; G = 2.95. Color bright peach-blossom-red; streak

paler. Luster adamantine to pearly, silky. In capillary tufts of crystals, also earthy. The common alteration of arsenides containing cobalt. An indication of cobalt ores.

b. Earthy, compact.

Erythrite, as above; often earthy.

BAUXITE, $Al_2O(OH)_4$, compact, earthy, oölitic. H = 1–2.5; G = 2.5. Color brick red, streak paler. Color is due to admixture of Fe_2O_3, much bauxite having an uncolored streak. The principal ore of aluminium.

(Compare *Hematite* below, when earthy H = under 4.5.)

c. Crystalline, or massive crystalline.

Realgar, AsS, V. H = 1.5–2; G = 3.56. Color aurora-red to orange-red; streak orange-red. Luster adamantine to resinous. Transparent. Rare.

CINNABAR, HgS, III R-trapezohedral. H = 2–2.5; G = 8–8.2. Color cochineal to brownish red; adamantine to metallic adamantine; streak vermilion. Crystals rhombohedral, prismatic; cleavage prismatic. Generally massive granular, in crusts, sometimes earthy. The principal ore of mercury.

PROUSTITE, Ag_3AsS_3, III R-hemimorphic. H = 2–2.5; G = 5.57–5.64. Color deep red; luster adamantine; streak red, on rubbing aurora red; translucent. Crystals acute, rhombohedral; also massive. An important silver ore.

PYRARGYRITE, Ag_3SbS_3, III R-hemimorphic. H = 2.5; G = 5.85. Color nearly black, submetallic to *metallic-adamantine*, by transmitted light deep red; *streak purplish red*, becoming aurora red on rubbing.

Crystals prismatic, obtuse; also compact massive and interspersed; fracture conchoidal to uneven. An important silver ore.

2. Hardness 2.5 to 4.5.

CUPRITE, Cu_2O, I. H = 3.5–4; G = 5.85–6.15. Color cochineal red to nearly black; luster adamantine to earthy; streak brick red. Crystals cubes, octahedrons, dodecahedrons, etc. Massive granular to earthy. Often associated with metallic copper. An important ore.

SPHALERITE, ZnS, I, tetrahedral. H = 3.5–4; G = 3.9–4.1. Streak sometimes reddish, see under brown streak above.

3. Hardness above 4.5.

a. Streak reddish.

PIEDMONTITE, $Ca_2(AlOH)(Mn,Al)_2(SiO_4)_3$, V. H = 6.5; G = 3.4. Reddish plum color; streak lighter; vitreous to pearly. Crystals prismatic to bladed; also massive compact. A rock-forming mineral in some crystalline schists, etc.

b. Streak bright red.

TURGITE, $Fe_4O_5(OH)_2$. Compact fibrous to massive. H = 5–6; G = 4.2–4.6. Color, when compact, dark red to nearly black; when earthy, bright red; streak bright ochre red. A splinter decrepitates in the flame of a match. A common iron ore.

HEMATITE, Fe_2O_3, III R. H = 5.5–6.5; G = 4.2–5.2. Color of non-metallic varieties generally dark red; streak bright cherry red. Generally compact, massive or fibrous when non-metallic; fracture uneven to splintery; also often earthy, scaly, etc. Common iron ore.

c. Streak dark red to reddish-black.

FRANKLINITE, $(Zn,Mn)Fe_2O_4$, I. H = 5.5–6.5; G =

5–5.2. Color iron black; luster vitreous sub-metallic; streak reddish-brown to reddish-black, paler on rubbing. Commonly in octahedrons or combinations of octahedron and dodecahedron; granular massive. Fracture small conchoidal to uneven. Magnetic, sometimes strongly so. An ore of zinc, manganese and iron.

Samarskite. Cerium-Yttrium niobate, IV. H = 5–6; G = 5.6–5.8. Color black; luster vitreous to resinous; streak dark reddish to brownish-red. Commonly massive, or in flattened forms, imbedded in the gangue. Fracture conchoidal, smooth. Affects a photographic plate.

Columbite and *Tantalite.* Niobate and Tantalate of iron and manganese, IV. H = 6; G = 5.3–7.3. Color iron-black, frequently with a steel-blue iridescence, luster submetallic; streak dark red to reddish-black. In tabular to short prismatic crystals, imbedded in the gangue, crystals sometimes large; rarely massive. Often found with tin ores.

IV. Streak yellow, brownish-yellow.

1. Hardness under 2.5, can be scratched with the finger-nail.

a. **Earthy, scaly massive.**

Tungstite, WO_3, IV. H = 1, earthy; G = 6. Color dull yellow, sometimes greenish or brownish-yellow. Streak same as the color. Luster dull. Commonly pulverulent and earthy. Associated with Wolframite, etc.

Molybdite, MoO_3, IV. H = 1–2; G = 4.5. Color and streak lemon-yellow; in silky crystals, more commonly dull, pulverulent and earthy. Associated with molybdenite. This may be a calcium molybdate.

Massicot, PbO, massive. H = 2; G = 8–9. Color sulphur to orpiment-yellow; streak pale sulphur yellow. Compact earthy or scaly massive. Not found in sufficient quantity to be a lead ore. Recognized by its high specific gravity.

Minium, Red Lead, Pb_3O_4. Earthy. H = 1–3; G = 4.6. Color vivid orange-red; streak orange. Luster dull, earthy. Pulverulent. Occurs with galenite, etc., but rare.

(Compare *Cervantite* below, sometimes soft, also *Greenockite*, often earthy.)

b. Crystalline or crystalline massive.

ORPIMENT, As_2S_3, V. H = 1.5–2; G = 3.4–3.5. Color lemon-yellow to orpiment-yellow; streak somewhat paler. Luster pearly to resinous. Columnar to foliated massive; cleavage pinacoidal; laminæ of cleavage flexible.

SULPHUR, S, IV. H = 1.5–2.5; G = 2. Color sulphur-yellow, sometimes honey-yellow; streak pale yellowish to white. In pyramidal crystals and massive; fracture conchoidal to uneven. Burns with evolution of SO_2 in match flame. Principal source of sulphur, etc.

Copiapite, $Fe(FeOH)_2(SO_4)_5 + 18H_2O$, V. H = 2.5; G = 2.1. Color sulphur-yellow; streak paler than the color. Luster pearly to earthy. Translucent to opaque. In scaly or granular masses and crusts. Taste sweetish-astringent and somewhat metallic.

Autunite, $Ca(VO_2)_2P_2O_8 + 8H_2O$, IV. H = 2–2.5; G = 3 05–3.2. Color lemon-yellow; streak yellowish; luster pearly-adamantine. In square tabular scaly crystals or micaceous, with strong basal cleavage. Associated with uraninite, gummite, etc.

2. Hardness 2.5–4.5.

a. Compact or earthy.

Gummite. Uranium oxides, etc. Amorphous. H = 2.5–3; G = 3.9–4.2. Color orange to reddish-yellow; dull to greasy luster; streak yellow. Associated with Autunite, Uraninite, etc.

Greenockite, CdS, III. H = 3–3.5; G = 4.9–5. Color honey-yellow to orange-yellow; streak orange-yellow. Luster resinous to dull. Commonly pulverulent, in coatings on sphalerite, etc.; crystals rare.

CERVANTITE, Sb_2O_4, IV. H = 4–5; G = 4. Color dull yellow, sulphur-yellow, pale buff to white; streak yellowish-white to white. Luster dull. Massive, in crusts and pulverulent; often pseudomorphous after stibnite. An antimony ore.

b. Cleavable.

SPHALERITE, ZnS. I, tetrahedral. H = 3.5–4; G = 3.9–4.1. Color, shades of yellow, brown and red; luster adamantine in crystals and on cleavage, resinous when massive; streak yellowish (also brownish, reddish, white). Crystals common, usually cleavable massive, cleavage parallel to the dodecahedron, perfect. Sometimes compact massive. The principal zinc ore.

WURTZITE, ZnS, III. Closely resembles sphalerite, but is fibrous-massive, or columnar.

ZINCITE, ZnO, III. H = 4–4.5; G = 5.4–5.7. Color deep red to orange-red; streak orange-yellow. Luster vitreous to subadamantine. Crystals very rare, cleavable massive to micaceous, cleavage basal. Occurs with Willemite, Franklinite, etc. Zinc ore.

c. Not belonging to the foregoing divisions.

Crocoite, $PbCrO_4$, V. H = 2.5–3; G = 5.9–6.1. Color bright hyacinth-red; streak orange-yellow. Luster adamantine to resinous. In crystals, columnar and granular massive. Fracture small conchoidal. Rare.

Jarosite, $K(FeO)_3(SO_4)_3 + 3H_2O$, III R. H = 2.5–3.5; G = 3.15–3.26. Color yellowish-brown to clove-brown; streak yellow; luster vitreous to subadamantine. In crusts on limonite, crystals common, rhombohedral. Rare.

PYROMORPHITE, $Pb_5Cl(PO_4)_3$, III. H. = 3.5–4; G = 6–7. Color green, yellow, brownish to white; streak yellowish to white. Resinous to subadamantine. In hexagonal prisms terminated by the basal plane; in reniform or botryoidal crusts; rarely massive. A surface alteration product from lead ores.

Thorite, ThO_2SiO_2, II. H = 4.5–5; G = 4.4–5.4. Color brownish-black, also orange-yellow, brownish-yellow, resinous to greasy; streak orange to brownish-yellow. In square prismatic crystals, also massive, compact. Fracture conchoidal. In the older crystalline rocks, also in monazite sand. Rare.

3. **Hardness above 4.5.**

LIMONITE, $Fe_4O_3(OH)_6$, IV. Fibrous massive, etc. See under *brown streak*.

GOETHITE, FeO(OH), IV. H = 5–5.5; G = 4–4.4. Color yellowish, reddish and blackish-brown; streak ochre-yellow. Luster of crystals submetallic, otherwise dull. In prismatic crystals, massive fibrous, scaly, etc. An important iron ore.

Microlite, $Ca_2Ta_2O_7 + NbOF_3$. I. H = 5.5; G = 5.5–6.1. Color yellowish to brown; streak yellowish to

brownish-yellow. In disseminated crystals, octahedral, often small. Rare.

(Compare Allanite, under *green streak*, which sometimes has a brownish streak.)

V. Streak green, including greenish-gray.

1. Hardness under 2.5, can be scratched with the finger-nail.

a. Micaceous crystalline.

Torbernite, $Cu(UO_2)_2P_2O_8 + H_2O$, II. H = 2–2.5; G = 3.4–3.6. Color emerald to apple-green, pearly adamantine; streak apple-green. Crystals square tabular, micaceous cleavage; also in foliated micaceous aggregates of crystals. Associated with *uraninite*, *autunite*, etc. Rare.

b. Earthy, compact or amorphous.

Annabergite, $Ni_3As_2O_8 + 8H_2O$, V. Soft and earthy. G = 3–3.1. Color apple-green; streak pale apple-green. Luster dull. *Nickel bloom*, an oxidation product of nickel arsenides. Rare.

GLAUCONITE, Hydrous silicate of potash and iron. Amorphous. H = 2; G = 2.2–2.4. Color olive-green to yellow-green; streak paler than color. Luster dull to greasy. Earthy to granular massive. The coloring of most greensand.

Wolchonskoite, Hydrous silicate of chromium, iron and aluminium. Amorphous. H = 2.25; G = 2.3. Color grass-green to bluish-green; streak paler, shining. Feels waxy, fracture sub-conchoidal, very fragile. Sometimes adheres to the tongue. Associated with chromite and serpentine.

GARNIERITE and *Genthite*, $H_2(Ni,Mg)SiO_4 + H_2O$. Amorphous. H = 1–3; G = 2.3–2.8. Color pale to

bright apple-green; streak pale green ; luster resinous to dull. Friable massive, pulverulent and encrusting. Associated with serpentine. Important nickel ores.

2. Hardness 2.5–4.5.

a. Amorphous.

Chloropal, $H_6Fe_2Si_3O_{12} + 2H_2O$. Amorphous. H = 2.5–4.5 (when dry) ; G = 1.7–1.9. Color pistachio-green to yellow-green ; streak greenish ; luster dull to greasy. Compact massive, with conchoidal to uneven fracture. Adheres slightly to the tongue.

CHRYSOCOLLA, $CuSiO_3 + 2H_2O$. Amorphous. H = 2.5–5; G = 2.2–2.4. Color bluish-green to bluish; streak greenish to white. Luster dull to vitreous. Compact to glassy texture, also earthy ; fracture conchoidal. Occurs with other copper ores. (Here belongs *Dioptase*, $CuSiO_3 + H_2O$, III.)

Zaratite, $NiCO_3.2Ni(OH)_2 + 4H_2O$. Amorphous. H = 3; G = 2.6–2.7. Color emerald-green; streak somewhat paler. Luster vitreous, transparent. In crusts, compact massive, associated with serpentine and chromite.

Compare also *Vauquelinite*, below, which is often compact.

b. Fibrous.

MALACHITE, $CuCO_3.Cu(OH)_2$, V. H = 3.5–4 ; G = 3.9–4. Color bright green; streak paler ; luster of crystals vitreous, compact varieties silky to dull, earthy. Distinct crystals rare, commonly encrusting, botryoidal and stalactitic ; texture fibrous, radiating. A common surface ore of copper, the usual surface indication of copper ore.

DUFRENITE, $FePO_4.Fe(OH)_3$, IV. H = 3.5–4 ; G =

3.2–3.4. Color blackish-green to dull leek-green; streak grayish-green; luster dull silky on fracture. Texture fibrous, radiating. In crusts and nodules. Occurs in the greensands, also with limonite. Compare also Olivenite, below, which is sometimes fibrous.

c. Micaceous.

Lepidomelane, $(H,K)_2Fe_3(Fe,Al)_4(SiO_4)_5$, V. H = 3; G = 3–3.2. Color black; streak grayish-green; luster adamantine to pearly. Micaceous, foliated; cleavage basal, eminent. A rock forming mineral in granites, etc.

d. Not included in the foregoing divisions.

Vauquelinite, phospho-chromate of lead, V. H = 2.5–3; G = 5.8–6.1. Color olive-green to brown; streak greenish; luster resinous. Crystals minute, encrusting, also compact reniform, botryoidal, or earthy. With Crocoite. rare.

Olivenite, $Cu_3As_2O_8.Cu(OH)_2$, IV. H = 3; G = 4.1–4.4. Color olive-green to blackish-green; streak olive-green. Luster of crystals adamantine. Crystals prismatic; also encrusting, globular, and reniform; texture sometimes fibrous.

Atacamite, $Cu_2Cl(OH)_3$, IV. H = 3–3.5; G = 3.75, Color dark emerald-green to blackish-green, also bright green; streak apple-green. Luster adamantine to vitreous. In slender prismatic crystals and aggregates of crystals, sometimes almost fibrous, also compact. An ore of copper.

Brochantite, $CuSO_4.3Cu(OH)_2$, IV. H = 3.5–4; G = 3.9. Color dark emerald-green to blackish-green; streak *pale emerald-green.* Luster vitreous. Crystals acicular, *generally in* crusts with a drusy surface, also reniform. *Rather rare.*

c. Not belonging to the foregoing divisions.

Crocoite, $PbCrO_4$, V. H = 2.5–3; G = 5.9–6.1. Color bright hyacinth-red; streak orange-yellow. Luster adamantine to resinous. In crystals, columnar and granular massive. Fracture small conchoidal. Rare.

Jarosite, $K(FeO)_3(SO_4)_3 + 3H_2O$, III R. H = 2.5–3.5; G = 3.15–3.26. Color yellowish-brown to clove-brown; streak yellow; luster vitreous to subadamantine. In crusts on limonite, crystals common, rhombohedral. Rare.

Pyromorphite, $Pb_5Cl(PO_4)_3$, III. H. = 3.5–4; G = 6–7. Color green, yellow, brownish to white; streak yellowish to white. Resinous to subadamantine. In hexagonal prisms terminated by the basal plane; in reniform or botryoidal crusts; rarely massive. A surface alteration product from lead ores.

Thorite, ThO_2SiO_2, II. H = 4.5–5; G = 4.4–5.4. Color brownish-black, also orange-yellow, brownish-yellow, resinous to greasy; streak orange to brownish-yellow. In square prismatic crystals, also massive, compact. Fracture conchoidal. In the older crystalline rocks, also in monazite sand. Rare.

3. **Hardness above 4.5.**

Limonite, $Fe_4O_3(OH)_6$, IV. Fibrous massive, etc. See under *brown streak*.

Goethite, FeO(OH), IV. H = 5–5.5; G = 4–4.4. Color yellowish, reddish and blackish-brown; streak ochre-yellow. Luster of crystals submetallic, otherwise dull. In prismatic crystals, massive fibrous, scaly, etc. An important iron ore.

Microlite, $Ca_2Ta_2O_7 + NbOF_3$. I. H = 5.5; G = 5.5–6.1. *Color* yellowish to brown; streak yellowish to

brownish-yellow. In disseminated crystals, octahedral, often small. Rare.

(Compare Allanite, under *green streak*, which sometimes has a brownish streak.)

V. Streak green, including greenish-gray.

1. Hardness under 2.5, can be scratched with the finger-nail.

a. Micaceous crystalline.

Torbernite, $Cu(UO_2)_2P_2O_8 + H_2O$, II. H = 2–2.5; G = 3.4–3.6. Color emerald to apple-green, pearly adamantine; streak apple-green. Crystals square tabular, micaceous cleavage; also in foliated micaceous aggregates of crystals. Associated with *uraninite*, *autunite*, etc. Rare.

b. Earthy, compact or amorphous.

Annabergite, $Ni_3As_2O_8 + 8H_2O$, V. Soft and earthy. G = 3–3.1. Color apple-green; streak pale apple-green. Luster dull. *Nickel bloom*, an oxidation product of nickel arsenides. Rare.

GLAUCONITE, Hydrous silicate of potash and iron. Amorphous. H = 2; G = 2.2–2.4. Color olive-green to yellow-green; streak paler than color. Luster dull to greasy. Earthy to granular massive. The coloring of most greensand.

Wolchonskoite, Hydrous silicate of chromium, iron and aluminium. Amorphous. H = 2.25; G = 2.3. Color grass-green to bluish-green; streak paler, shining. Feels waxy, fracture sub-conchoidal, very fragile. Sometimes adheres to the tongue. Associated with chromite and serpentine.

GARNIERITE and *Genthite*, $H_2(Ni,Mg)SiO_4 + H_2O$. Amorphous. H = 1–3; G = 2.3–2.8. Color pale to

bright apple-green; streak pale green; luster resinous to dull. Friable massive, pulverulent and encrusting. Associated with serpentine. Important nickel ores.

2. Hardness 2.5–4.5.

a. Amorphous.

Chloropal, $H_6Fe_2Si_3O_{12} + 2H_2O$. Amorphous. H = 2.5–4.5 (when dry); G = 1.7–1.9. Color pistachio-green to yellow-green; streak greenish; luster dull to greasy. Compact massive, with conchoidal to uneven fracture. Adheres slightly to the tongue.

CHRYSOCOLLA, $CuSiO_3 + 2H_2O$. Amorphous. H = 2.5–5; G = 2.2–2.4. Color bluish-green to bluish; streak greenish to white. Luster dull to vitreous. Compact to glassy texture, also earthy; fracture conchoidal. Occurs with other copper ores. (Here belongs *Dioptase*, $CuSiO_3 + H_2O$, III.)

Zaratite, $NiCO_3.2Ni(OH)_2 + 4H_2O$. Amorphous. H = 3; G = 2.6–2.7. Color emerald-green; streak somewhat paler. Luster vitreous, transparent. In crusts, compact massive, associated with serpentine and chromite.

Compare also *Vauquelinite*, below, which is often compact.

b. Fibrous.

MALACHITE, $CuCO_3.Cu(OH)_2$, V. H = 3.5–4; G = 3.9–4. Color bright green; streak paler; luster of crystals vitreous, compact varieties silky to dull, earthy. Distinct crystals rare, commonly encrusting, botryoidal and stalactitic; texture fibrous, radiating. A common surface ore of copper, the usual surface indication of copper ore.

DUFRENITE, $FePO_4.Fe(OH)_3$, IV. H = 3.5–4; G =

3.2–3.4. Color blackish-green to dull leek-green; streak grayish-green; luster dull silky on fracture. Texture fibrous, radiating. In crusts and nodules. Occurs in the greensands, also with limonite. Compare also Olivenite, below, which is sometimes fibrous.

c. Micaceous.

Lepidomelane, $(H,K)_2Fe_3(Fe,Al)_4(SiO_4)_5$, V. H = 3; G = 3–3.2. Color black; streak grayish-green; luster adamantine to pearly. Micaceous, foliated; cleavage basal, eminent. A rock forming mineral in granites, etc.

d. Not included in the foregoing divisions.

Vauquelinite, phospho-chromate of lead, V. H = 2.5–3; G = 5.8–6.1. Color olive-green to brown; streak greenish; luster resinous. Crystals minute, encrusting, also compact reniform, botryoidal, or earthy. With Crocoite. rare.

Olivenite, $Cu_3As_2O_8.Cu(OH)_2$, IV. H = 3; G = 4.1–4.4. Color olive-green to blackish-green; streak olive-green. Luster of crystals adamantine. Crystals prismatic; also encrusting, globular, and reniform; texture sometimes fibrous.

Atacamite, $Cu_2Cl(OH)_3$, IV. H = 3–3.5; G = 3.75, Color dark emerald-green to blackish-green, also bright green; streak apple-green. Luster adamantine to vitreous. In slender prismatic crystals and aggregates of crystals, sometimes almost fibrous, also compact. An ore of copper.

Brochantite, $CuSO_4.3Cu(OH)_2$, IV. H = 3.5–4; G = 3.9. Color dark emerald-green to blackish-green; streak pale emerald-green. Luster vitreous. Crystals acicular, generally *in crusts with a drusy surface, also reniform. Rather rare.*

Libethenite, $Cu_3P_2O_8.Cu(OH)_2$, IV. H = 4; G = 3.6–3.8. Color dark olive-green; streak olive-green. Luster of crystals resinous; crystals short, prismatic, resembling octahedrons; commonly in drusy crusts. Rather rare.

ALABANDITE, MnS, I. Tetrahedral. H = 3.5-4; G = 3.9–4. Color greenish iron-black, submetallic, tarnishing dull brownish-black; streak green. Commonly cleavable massive, cleavage cubical, perfect; crystals cubical, rare.

Hardness 4.5 to 6; can be scratched with a knife.

a. Cleavable.

HORNBLENDE, $Ca(Mg,Fe)_5(SiO_3)_4 + Al_2(Mg,Fe)_2(SiO_3)_2(AlO_3)_2$, V. H = 5.5; G = 3–3.5. Color greenish-black to dark green; streak grayish-green; luster vitreous to somewhat silky in the fibrous varieties. Cleavage prismatic, angle 124°, in crystals, cleavable massive to fibrous massive. A common rock-making mineral in metamorphic igneous rocks.

PYROXENE in the varieties AUGITE, $CaMgSi_2O_6 + (Mg,Fe)(Al,Fe)_2SiO_6$, V, and HEDENBERGITE, $CaFeSi_2O_6$, V. H = 5.5–6; G = 3–3.5. Color greenish and brownish-black; streak grayish-green; luster vitreous. In crystals and massive cleavable, cleavage prismatic, angle = 87°; also often with partings parallel to basal and ortho-pinacoids; usually more brownish than hornblende. A common rock-making mineral in igneous rocks, etc.

b. Not cleavable.

ALLANITE, $H(Ca,Fe)(Al,Fe,Ce)_3Si_3O_{13}$, V. H = 5.5–6; G = 3–4.2. Color pitchy-black to brown-black;

luster pitchy to resinous; streak greenish-gray to gray. In tabular and prismatic crystals, also irregular masses and grains in granite, etc. A rock making mineral. By weathering it changes to dull brick red.

4. Hardness above 6, cannot be scratched with a knife.

Gadolinite, $Be_2Fe_2Y_2Si_2O_{10}$, V. H = 6.5–7; G = 4–4.5. Color vitreous black to greenish black, by transmitted light in thin splinters olive green; streak greenish gray; luster vitreous inclining to greasy. Weathers to a dull brick red. Crystals rough, rather rare. More commonly massive. Luster more vitreous than Allanite. Rare.

Uvarovite, chrome garnet. $Ca_3Cr_2(SiO_4)_3$, I. H = 7.5; G = 3.4–3.5. Color emerald green; streak paler. Luster vitreous. In dodecahedrons and trapezohedrons, Recognized by its form and color. Rare.

Hercynite, $FeAl_2O_4$, I. H = 7.5–8; G = 3.95. Color black, vitreous; streak leek green. Commonly pseudomorphous after corundum, or massive. With corundum, magnetite, etc., rather rare.

VI. Streak blue, grayish blue.

1. Hardness under 2.5 can be scratched with the finger-nail.

VIVIANITE, $Fe_3P_2O_8 + 8H_2O$, V. H = 1.5–3; G = 2.58–2.68. Color blue, greenish blue, colorless, pleochroic; luster pearly to vitreous; streak bluish to colorless. Crystals prismatic to tabular, cleavage clinopinacoidal, perfect; also massive fibrous to earthly and encrusting, pseudomorphous after fossils, etc. A source of phosphoric acid for fertilizers. In greensand, *etc., and in mineral* veins.

Liroconite, Hydrous arsenate of Al and Cu, V. H =

2.5; G = 2.9–3. Color and streak sky blue to greenish blue; luster vitreous. Crystals octahedral, also granular. Rare.

Linarite $(Pb,Cu)SO_4.(Pb,Cu)(OH)_2$, V. H = 2.5; G = 5.3–5.4. Color azure blue, streak paler; luster vitreous to subadamantine. In prismatic to tabular crystals, encrusting. Rare.

2 Hardness 2 5 to 4 5.

Crocidolite, $NaFeSi_2O_6FeSiO_3$, V. Fibrous, asbestus-like. H = 2.5–4; G = 3.23.3. Color deep lavender blue; streak somewhat paler; luster silky. Very fibrous, fibers long and delicate, elastic; also massive fibrous. Rather rare.

AZURITE, $2CuCO_3.Cu(OH)_2$, V. H = 3.5–4; G = 3.77–3.83. Color azure blue to Berlin blue; streak paler blue. Luster vitreous to subadamantine. Crystals short prismatic, resembling rhombohedra; also in crusts, massive compact to earthy. An important surface ore of copper.

3. Hardness above 4.5.

Lazurite, $Na_4(NaS_3.Al)Al_2(SiO_4)_3$, I. H = 5–5.5; G = 2.4–2.45. Color azure blue, Berlin blue; streak pale ultramine blue; luster vitreous. Commonly massive, compact. Recognized by its color. Used for ornament, etc.; rare.

Arfvedsonite, $(Fe,Na_2,Ca,Mg)_4Si_4O_{12}$, V. H = 6; G = 3.45. Color black; luster vitreous; streak bluish gray. In long prismatic crystals and aggregates, also cleavable massive; cleavage prismatic with angle of 124°. *A rock making* mineral in nepheline syenite, phonolite, *etc.*

Glaucophane, $NaAl(SiO_3)_2.(FeMg)SiO_3$, V. H = 6

6.5; G = 3.1. Color dark grayish blue, bluish black; streak grayish blue; luster pearly to vitreous. In long bladed crystals and fibrous to blade-like massive aggregations; cleavage prismatic, perfect, with angle of 122°. Pleochroism strong. A rock-making mineral in certain schists.

C. STREAK UNCOLORED (OR VERY SLIGHTLY TINTED).

I. Hardness not above 2.5; may be scratched with the finger-nail.

1. Soluble in water, giving a taste when placed upon the tongue.

a. Taste saline.

CARNALLITE, $KMgCl_3 + 6H_2O$, IV. H = 1; G = 1.6. Colorless to pinkish, greasy to vitreous. Granular massive. Taste, saline, then bitter. Deliquescent. One of the Stassfurt potash salts.

SAL AMMONIAC, NH_4Cl, I. H = 1.5–2; G = 1.53. Colorless; luster vitreous to greasy. In crusts, as an efflorescence, fibrous massive. Taste, sharp saline.

SYLVITE, KCl, I. H = 2; G = 2. Colorless, luster vitreous. In cubes and cubo-octahedrons, cleavage cubic, perfect. Taste, somewhat sharper that Halite. A Stassfurt potash salt.

HALITE, *Common salt*, NaCl, I. H = 2 5; G = 2.1–2.2. Colorless or colored by impurities. Luster vitreous; commonly in cubes, cleavage cubic, perfect; also in cleavable massive form. Taste, saline. *Common in beds, as rock* salt; in solution in salt springs, *in the sea, etc.*

b. Taste cooling.

SODA NITER, $NaNO_3$, III R. H = 1.5–2; G = 2.24–2.29. Colorless, vitreous. Granular massive, in beds; also incrusting. Taste cooling. *Chili saltpetre* from Tarapaca, Chili, etc.

Niter, KNO_3, IV. H = 2; G = 2.1. Colorless; vitreous. In crusts of acicular crystals, in tufts, etc. Taste, cooling and somewhat saline. In certain soils, in caves, etc.

c. Taste alkaline.

THERMONATRITE, $Na_2CO_3 + H_2O$, IV. H = 1–1.5; G = 1.5–1.6. Color white, yellowish, grayish. Usually an efflorescence, dull, earthy. Taste, alkaline. Results from efflorescence of Natron.

NATRON, $Na_2CO_3 + 10H_2O$, V. H = 1–1.5; G = 1.45. Color white to grayish. Vitreous, becoming dull by efflorescence. Crystals tabular, efflorescing. Taste alkaline. Common with the last in "alkaline earth," etc. Here belongs TRONA when *earthy*, see p. 333.

d. Taste bitter.

MIRABILITE, $Na_2SO_4.10H_2O$, V. H = 1.5–2; G = 1.48. Colorless, vitreous, becoming dull by efflorescence. Taste, faintly bitter and cooling. Common as an efflorescence on alkaline earth and in many salt lakes, etc.

EPSOMITE, $MgSO_4+7H_2O$, IV. H = 2–2.5; G = 1.75. Colorless and vitreous to dull white. In fibrous masses and crusts; efflorescing. Taste, bitter and somewhat saline. In caves, mines, etc., and dissolved in many waters.

Thenardite, Na_2SO_4, IV. H = 2–3; G = 2.7. Color-

less to dull brownish; vitreous. Crystals flat, often twinned. Taste, slightly bitter. In salt lake deposits.

e. Taste acid.

SASSOLITE, $B(OH)_3$, VI. H = 1; G = 1.48. Color white, yellowish; pearly; in scaly crystals. Taste, acid, somewhat bitter. Greasy to the touch. Often in solution in hot springs.

f. Taste sweetish and sweetish-astringent.

Arsenolite, As_2O_3, I. H = 1.5; G = 3.7. Colorless to white, vitreous. In crusts, botryoidal and earthy. Taste, sweetish-astringent. *A poison.*

Alunogen, $Al_2(SO_4)_3 + 18H_2O$, V. H = 1.5–2; G = 1.6–1.8. Color white, yellowish, silky to dull. In crusts, fibrous massive to compact. Taste, sweetish-astringent.

Kalinite, $KAl(SO_4)_2 + 12H_2O$, I. H = 2–2.5; G = 1.75. Colorless, vitreous; in crusts, fibrous massive or earthy. Taste, sweetish-astringent.

MELANTERITE, $FeSO_4 + 7H_2O$, V. H = 2; G = 1.8–1.9. Color pale green, vitreous; becoming yellow and earthy by exposure. In crusts, fibrous massive to earthy. Taste sweetish, astringent and metallic. Produced by oxidation of marcasite, pyrite, etc.

Coquimbite, $Fe_2(SO_4)_3 + 9H_2O$, III R. H = 2–2.5. G = 2.1. Color white, yellowish or pale violet. Granular massive, more rarely in crystals; becoming dull yellow on the surface from exposure. Taste, astringent and sweetish. Rare.

BORAX, $Na_2B_4O_7 + 10H_2O$, V. H = 2–2.5: G = 1.7. Colorless, white; vitreous to dull white from efflorescence. *Usually* in prismatic crystals, often large.

c. Not belonging to the foregoing divisions.

Crocoite, $PbCrO_4$, V. H = 2.5–3; G = 5.9–6.1. Color bright hyacinth-red; streak orange-yellow. Luster adamantine to resinous. In crystals, columnar and granular massive. Fracture small conchoidal. Rare.

Jarosite, $K(FeO)_3(SO_4)_3 + 3H_2O$, III R. H = 2.5–3.5; G = 3.15–3.26. Color yellowish-brown to clove-brown; streak yellow; luster vitreous to subadamantine. In crusts on limonite, crystals common, rhombohedral. Rare.

Pyromorphite, $Pb_5Cl(PO_4)_3$, III. H. = 3.5–4; G = 6–7. Color green, yellow, brownish to white; streak yellowish to white. Resinous to subadamantine. In hexagonal prisms terminated by the basal plane; in reniform or botryoidal crusts; rarely massive. A surface alteration product from lead ores.

Thorite, ThO_2SiO_2, II. H = 4.5–5; G = 4.4–5.4. Color brownish-black, also orange-yellow, brownish-yellow, resinous to greasy; streak orange to brownish-yellow. In square prismatic crystals, also massive, compact. Fracture conchoidal. In the older crystalline rocks, also in monazite sand. Rare.

3. **Hardness above 4.5.**

Limonite, $Fe_4O_3(OH)_6$, IV. Fibrous massive, etc. See under *brown streak*.

Goethite, FeO(OH), IV. H = 5–5.5; G = 4–4.4. Color yellowish, reddish and blackish-brown; streak ochre-yellow. Luster of crystals submetallic, otherwise dull. In prismatic crystals, massive fibrous, scaly, etc. An important iron ore.

Microlite, $Ca_2Ta_2O_7 + NbOF_3$. I. H = 5.5; G = 5.5–6.1. *Color* yellowish to brown; streak yellowish to

brownish-yellow. In disseminated crystals, octahedral, often small. Rare.

(Compare Allanite, under *green streak*, which sometimes has a brownish streak.)

V. Streak green, including greenish-gray.

1. Hardness under 2.5, can be scratched with the finger-nail.

a. Micaceous crystalline.

Torbernite, $Cu(UO_2)_2P_2O_8 + H_2O$, II. H = 2–2.5; G = 3.4–3.6. Color emerald to apple-green, pearly adamantine; streak apple-green. Crystals square tabular, micaceous cleavage; also in foliated micaceous aggregates of crystals. Associated with *uraninite*, *autunite*, etc. Rare.

b. Earthy, compact or amorphous.

Annabergite, $Ni_3As_2O_8 + 8H_2O$, V. Soft and earthy. G = 3–3.1. Color apple-green; streak pale apple-green. Luster dull. *Nickel bloom*, an oxidation product of nickel arsenides. Rare.

GLAUCONITE, Hydrous silicate of potash and iron. Amorphous. H = 2; G = 2.2–2.4. Color olive-green to yellow-green; streak paler than color. Luster dull to greasy. Earthy to granular massive. The coloring of most greensand.

Wolchonskoite, Hydrous silicate of chromium, iron and aluminium. Amorphous. H = 2.25; G = 2.3. Color grass-green to bluish-green; streak paler, shining. Feels waxy, fracture sub-conchoidal, very fragile. Sometimes adheres to the tongue. Associated with chromite and serpentine.

GARNIERITE and *Genthite*, $H_2(Ni,Mg)SiO_4 + H_2O$. Amorphous. H = 1–3; G = 2.3–2.8. Color pale to

bright apple-green; streak pale green; luster resinous to dull. Friable massive, pulverulent and encrusting. Associated with serpentine. Important nickel ores.

2. Hardness 2.5–4.5.

a. Amorphous.

Chloropal, $H_6Fe_2Si_2O_{12} + 2H_2O$. Amorphous. H = 2.5–4.5 (when dry); G = 1.7–1.9. Color pistachio-green to yellow-green; streak greenish; luster dull to greasy. Compact massive, with conchoidal to uneven fracture. Adheres slightly to the tongue.

CHRYSOCOLLA, $CuSiO_3 + 2H_2O$. Amorphous. H = 2.5–5; G = 2.2–2.4. Color bluish-green to bluish; streak greenish to white. Luster dull to vitreous. Compact to glassy texture, also earthy; fracture conchoidal. Occurs with other copper ores. (Here belongs *Dioptase*, $CuSiO_3 + H_2O$, III.)

Zaratite, $NiCO_3.2Ni(OH)_2 + 4H_2O$. Amorphous. H = 3; G = 2.6–2.7. Color emerald-green; streak somewhat paler. Luster vitreous, transparent. In crusts, compact massive, associated with serpentine and chromite.

Compare also *Vauquelinite*, below, which is often compact.

b. Fibrous.

MALACHITE, $CuCO_3.Cu(OH)_2$, V. H = 3.5–4; G = 3.9–4. Color bright green; streak paler; luster of crystals vitreous, compact varieties silky to dull, earthy. Distinct crystals rare, commonly encrusting, botryoidal and stalactitic; texture fibrous, radiating. A common surface ore of copper, the usual surface indication of copper ore.

DUFRENITE, $FePO_4.Fe(OH)_3$, IV. H = 3.5–4; G =

3.2–3.4. Color blackish-green to dull leek-green; streak grayish-green; luster dull silky on fracture. Texture fibrous, radiating. In crusts and nodules. Occurs in the greensands, also with limonite. Compare also Olivenite, below, which is sometimes fibrous.

c. Micaceous.

Lepidomelane, $(H,K)_2Fe_3(Fe,Al)_4(SiO_4)_5$, V. H = 3; G = 3–3.2. Color black; streak grayish-green; luster adamantine to pearly. Micaceous, foliated; cleavage basal, eminent. A rock forming mineral in granites, etc.

d. Not included in the foregoing divisions.

Vauquelinite, phospho-chromate of lead, V. H = 2.5–3; G = 5.8–6.1. Color olive-green to brown; streak greenish; luster resinous. Crystals minute, encrusting, also compact reniform, botryoidal, or earthy. With Crocoite. rare.

Olivenite, $Cu_3As_2O_8.Cu(OH)_2$, IV. H = 3; G = 4.1–4.4. Color olive-green to blackish-green; streak olive-green. Luster of crystals adamantine. Crystals prismatic; also encrusting, globular, and reniform; texture sometimes fibrous.

Atacamite, $Cu_2Cl(OH)_3$, IV. H = 3–3.5; G = 3.75, Color dark emerald-green to blackish-green, also bright green; streak apple-green. Luster adamantine to vitreous. In slender prismatic crystals and aggregates of crystals, sometimes almost fibrous, also compact. An ore of copper.

Brochantite, $CuSO_4.3Cu(OH)_2$, IV. H = 3.5–4; G = 3.9. Color dark emerald-green to blackish-green; streak *pale emerald-green.* Luster vitreous. Crystals acicular, *generally in crusts* with a drusy surface, also reniform. *Rather rare.*

c. Not belonging to the foregoing divisions.

Crocoite, $PbCrO_4$, V. H = 2.5–3; G = 5.9–6.1. Color bright hyacinth-red; streak orange-yellow. Luster adamantine to resinous. In crystals, columnar and granular massive. Fracture small conchoidal. Rare.

Jarosite, $K(FeO)_3(SO_4)_3 + 3H_2O$, III R. H = 2.5–3.5; G = 3.15–3.26. Color yellowish-brown to clove-brown; streak yellow; luster vitreous to subadamantine. In crusts on limonite, crystals common, rhombohedral. Rare.

PYROMORPHITE, $Pb_5Cl(PO_4)_3$, III. H. = 3.5–4; G = 6–7. Color green, yellow, brownish to white; streak yellowish to white. Resinous to subadamantine. In hexagonal prisms terminated by the basal plane; in reniform or botryoidal crusts; rarely massive. A surface alteration product from lead ores.

Thorite, ThO_2SiO_2, II. H = 4.5–5; G = 4.4–5.4. Color brownish-black, also orange-yellow, brownish-yellow, resinous to greasy; streak orange to brownish-yellow. In square prismatic crystals, also massive, compact. Fracture conchoidal. In the older crystalline rocks, also in monazite sand. Rare.

3. **Hardness above 4.5.**

LIMONITE, $Fe_4O_3(OH)_6$, IV. Fibrous massive, etc. See under *brown streak*.

GOETHITE, FeO(OH), IV. H = 5–5.5; G = 4–4.4. Color yellowish, reddish and blackish-brown; streak ochre-yellow. Luster of crystals submetallic, otherwise dull. In prismatic crystals, massive fibrous, scaly, etc. An important iron ore.

Microlite, $Ca_2Ta_2O_7 + NbOF_3$. I. H = 5.5; G = 5.5–6.1. Color yellowish to brown; streak yellowish to

brownish-yellow. In disseminated crystals, octahedral, often small. Rare.

(Compare Allanite, under *green streak*, which sometimes has a brownish streak.)

V. Streak green, including greenish-gray.

1. Hardness under 2.5, can be scratched with the finger-nail.

a. Micaceous crystalline.

Torbernite, $Cu(UO_2)_2P_2O_8 + H_2O$, II. H = 2–2.5; G = 3.4–3.6. Color emerald to apple-green, pearly adamantine; streak apple-green. Crystals square tabular, micaceous cleavage; also in foliated micaceous aggregates of crystals. Associated with *uraninite*, *autunite*, etc. Rare.

b. Earthy, compact or amorphous.

Annabergite, $Ni_3As_2O_8 + 8H_2O$, V. Soft and earthy. G = 3–3.1. Color apple-green; streak pale apple-green. Luster dull. *Nickel bloom*, an oxidation product of nickel arsenides. Rare.

GLAUCONITE, Hydrous silicate of potash and iron. Amorphous. H = 2; G = 2.2–2.4. Color olive-green to yellow-green; streak paler than color. Luster dull to greasy. Earthy to granular massive. The coloring of most greensand.

Wolchonskoite, Hydrous silicate of chromium, iron and aluminium. Amorphous. H = 2.25; G = 2.3. Color grass-green to bluish-green; streak paler, shining. Feels waxy, fracture sub-conchoidal, very fragile. Sometimes adheres to the tongue. Associated with chromite and serpentine.

GARNIERITE and Genthite, $H_2(Ni,Mg)SiO_4 + H_2O$. *Amorphous.* H = 1–3; G = 2.3–2.8. Color pale

bright apple-green; streak pale green ; luster resinous to dull. Friable massive, pulverulent and encrusting. Associated with serpentine. Important nickel ores.

2. Hardness 2.5–4.5.

a. Amorphous.

Chloropal, $H_6Fe_2Si_3O_{12} + 2H_2O$. Amorphous. H= 2.5–4.5 (when dry) ; G=1.7–1.9. Color pistachio-green to yellow-green ; streak greenish ; luster dull to greasy. Compact massive, with conchoidal to uneven fracture. Adheres slightly to the tongue.

CHRYSOCOLLA, $CuSiO_3 + 2H_2O$. Amorphous. H= 2.5–5; G = 2.2–2.4. Color bluish-green to bluish; streak greenish to white. Luster dull to vitreous. Compact to glassy texture, also earthy ; fracture conchoidal. Occurs with other copper ores. (Here belongs *Dioptase*, $CuSiO_3 + H_2O$, III.)

Zaratite, $NiCO_3.2Ni(OH)_2+4H_2O$. Amorphous. H= 3; G = 2.6–2.7. Color emerald-green; streak somewhat paler. Luster vitreous, transparent. In crusts, compact massive, associated with serpentine and chromite.

Compare also *Vauquelinite*, below, which is often compact.

b. Fibrous.

MALACHITE, $CuCO_3.Cu(OH)_2$, V. H=3.5–4 ; G= 3.9–4. Color bright green; streak paler ; luster of crystals vitreous, compact varieties silky to dull, earthy. Distinct crystals rare, commonly encrusting, botryoidal and stalactitic ; texture fibrous, radiating. A common surface ore of copper, the usual surface indication of *copper ore.*

DUFRENITE, $FePO_4.Fe(OH)_3$, IV. H=3.5–4 ; G=

3.2–3.4. Color blackish-green to dull leek-green; streak grayish-green; luster dull silky on fracture. Texture fibrous, radiating. In crusts and nodules. Occurs in the greensands, also with limonite. Compare also Olivenite, below, which is sometimes fibrous.

c. Micaceous.

Lepidomelane, $(H,K)_2Fe_3(Fe,Al)_4(SiO_4)_6$, V. H = 3; G = 3–3.2. Color black; streak grayish-green; luster adamantine to pearly. Micaceous, foliated; cleavage basal, eminent. A rock forming mineral in granites, etc.

d. Not included in the foregoing divisions.

Vauquelinite, phospho-chromate of lead, V. H = 2.5–3; G = 5.8–6.1. Color olive-green to brown; streak greenish; luster resinous. Crystals minute, encrusting, also compact reniform, botryoidal, or earthy. With Crocoite. rare.

Olivenite, $Cu_3As_2O_8.Cu(OH)_2$, IV. H = 3; G = 4.1–4.4. Color olive-green to blackish-green; streak olive-green. Luster of crystals adamantine. Crystals prismatic; also encrusting, globular, and reniform; texture sometimes fibrous.

Atacamite, $Cu_2Cl(OH)_3$, IV. H = 3–3.5; G = 3.75, Color dark emerald-green to blackish-green, also bright green; streak apple-green. Luster adamantine to vitreous. In slender prismatic crystals and aggregates of crystals, sometimes almost fibrous, also compact. An ore of copper.

Brochantite, $CuSO_4.3Cu(OH)_2$, IV. H = 3.5–4; G = 3.9. Color dark emerald-green to blackish-green; streak *pale emerald-green*. Luster vitreous. Crystals acicular, *generally in crusts* with a drusy surface, also reniform. *Rather rare.*

ARAGONITE, $CaCO_3$, IV. Prismatic to fibrous massive, etc. H = 3.5–4; G = 2.95. Colorless to white, grayish; luster vitreous, somewhat resinous on fracture. In pseudohexagonal prismatic crystals, cleavage parallel to the brachypinacoid, distinct; fracture subconchoidal. Also fibrous massive, stalactitic, encrusting. In beds of gypsum, limonite, deposits from hot springs, etc. The cleavage is not very marked.

STILBITE, $H_4(Na_2,Ca)Al_2Si_6O_{18}+4H_2O$, V. Prismatic, in sheaf-like aggregates. H = 3.5–4; G = 2–2.2. Color white, yellowish, brownish; luster pearly on (010), otherwise vitreous. Cleavage parallel to (010), the clinopinacoid, perfect. Crystals often flat, also in sheaf-like aggregates. Also radiating fibrous and encrusting, or in seams, etc. A secondary mineral in igneous rocks such as basalts, granite, gabbro, etc.

HEULANDITE, $H_4CaAl_2(SiO_3)_6+3H_2O$, V. Crystals coffin-shaped. H = 3.5–4; G = 2.2. Color white, brownish, reddish; luster on (010) pearly, otherwise vitreous. Cleavage clinopinacoidal, perfect. In crusts and filling seams in the rock like the last.

Apophyllite, $H_7KCa_4(SiO_3)_8+4\frac{1}{2}H_2O$, II, pyramidal and square prismatic. H = 4.5–5; G = 2.3–2.4. Colorless, grayish, pinkish; luster vitreous except on the basal pinacoid, which is pearly. Cleavage basal, perfect. Generally in four-sided pyramids terminating a square prism of opposite order; more rarely massive lamellar. In crusts, like the last.

Colemanite, $Ca_2B_6O_{11}+5H_2O$, V. Short prismatic, also massive cleavable to granular. H = 4–4.5; G = 2.4. Colorless to white, brilliant vitreous. Transparent. Usually in crystals, cleavage clinopinacoidal,

rfect; also basal, imperfect. In certain salt-lake desits in California and Missouri. A source of boric d, etc.

Compare also *Phillipsite*, *Laumontite*, *Harmotome*, low, which show pinacoidal cleavage.

. Cleavage prismatic.

CALAMINE, H_2ZnSiO_5, IV, hemimorphic, tabular, in eaf-like aggregates, and drusy. H = 4–4.5; G = 1–3.5. Colorless, white, bluish; vitreous. Cleavage ismatic, perfect; fracture fibrous to columnar. In sts, stalactitic; crystals strongly pyro-electric. An portant surface ore of zinc.

. Cleavage octahedral.

FLUORITE, CaF_2, I. Cubic and octahedral; cleavable d columnar massive. H = 4; G = 3.1–3.2. Colorss, purple, green, yellow, rarely red, pink; sometimes th a bluish fluorescence; luster vitreous. Cleavage tahedral, perfect. Phosphoresces on heating. With ineral veins, in limestones, etc. The source of hydroloric acid for glass etching, etc.

g. Cleavage rhombohedral.

CALCITE, $CaCO_3$, III R. Scalenohedral, rhombohe-al, prismatic, also massive granular. H = 3; G = 7. Colorless, white, yellowish-reddish; when massive also bluish to gray. Cleavage, perfect, angle 105°; most always observable. In crystals, massive granur, stalactitic, encrusting, etc. Effervesces strongly ith cold dilute HCl on the cleavage face or crystal. alcite is the basis of most limestones, common as a ngue mineral in ore veins, etc. Impure clay limeones are often valuable for hydraulic cement.

DOLOMITE, $(Ca,Mg)CO_3$, III R. Rhombohedral habit, also cleavable massive. H =3.5–4; G = 2.8–2.9. Color grayish-white, pinkish-white, creamy-white; luster vitreous, but often pearly. Cleavage perfect, angle 106° 15′. Rhombohedron and cleavage faces generally curved, even in massive forms Does not effervesce when a drop of cold dilute HCl is placed upon a crystal or cleavage face. Dolomite is the basis of many limestones, and when high in magnesia is used for some furnace linings. (See Magnesite above.)

Ankerite, $(Ca,Mg,Fe,Mn)CO_3$, III R. Closely resembles dolomite, but becomes rusty on weathering. Compare also Magnesite above, sometimes cleavable; in division 2. H = 3.5–4; G = 3.8–3.9.

RHODOCHROSITE has strong rhombohedral cleavage (G = 3.5–3.6), as has also Siderite (G = 3.8–3.9), see division 2 below.

Chabazite, $(CaNa_2)Al_2Si_4O_{12} + 6H_2O$, III R. Habit rhombohedral, twinned. H. =4–5; G = 2–2.15. Color white, flesh-red, pinkish. Cleavage distinct, angle 95°. In crusts or lining cavities, fissures, etc., in altered igneous rocks.

h. Not included in the foregoing division.

Laumontite, $H_4CaAl_2Si_4O_{14} + 2H_2O$, V. Prisms with an oblique termination. H = 3.5–4; G = 2.25–2.35. White, yellowish; becomes opaque white, and pulverulent on exposure to air. Luster vitreous to pearly. Crystals generally small; encrusting, also columnar, radiating. A secondary mineral in basalts, syenites, etc.

Phillipsite, $(K_2Ca)Al_2Si_4O_{12} + 4\frac{1}{2}H_2O$, V, pseudo-*orthorhombic*, penetration twins cruciform. H = 4–

ł.5; G = 2.2. White; vitreous. Crystals small. In basalts, etc.

Harmotome, $H_2(K_2Ba)Al_2Si_5O_{16} + 4H_2O$, V, pseudo-orthorhombic. Closely resembles the last, crystals generally larger. H = 4.5; G = 2.4—2.5. Colorless, white, gray, yellowish; luster vitreous. In basalts, etc.

2. Specific gravity above 3.5—feels decidedly heavy.

a. Easily cleavable.

SPHALERITE, ZnS, I, tetrahedral. Cleavage dodecahedral (110). H = 3.4–4; G = 3.9–4.1. Shades of yellow, red, brown, sometimes colorless. Luster adamantine to resinous. Streak sometimes yellowish, reddish, brownish, generally nearly white except in the very dark colored varieties. In crystals, cleavable massive to compact. The most important ore of zinc. Associated with galenite, pyrite, chalcopyrite, etc.

SIDERITE, $FeCO_3$, III R. Habit rhombohedral, cleavage rhombohedral. In crusts, also cleavable massive to compact, sometimes fibrous massive. H = 3.5–4; G = 3.8–3.9. Color yellowish gray, brownish; luster pearly to vitreous; when compact, dull glistening. In crusts and masses, also botryoidal and globular, concretionary; crystals have curved faces. An important ore of iron.

RHODOCHROSITE, $MnCO_3$, III R. Massive cleavable, also compact. Cleavage rhombohedral. H = 3.5–4.5; G = 3.45–3.6. Color rose pink, flesh colored; luster vitreous. Occurs in mineral veins carrying lead, silver, copper, etc.

BARITE, $BaSO_4$, IV. Cleavage prismatic, angle 101°

38′, and basal. Habit tabular and prismatic. H= 2.5–3.5; G = 4.3–4.6. Color white, also shades of yellow, brown, red, blue, green. Luster vitreous to resinous. Crystals common, also cleavable massive; more rarely fibrous and compact. A common gangue mineral with ores of the heavy metals, also in distinct veins. Used for white paint, to weight paper, etc.

CELESTITE, $SrSO_4$, IV. Cleavage basal and prismatic, prism angle 104° 10′. Habit tabular and prismatic. H = 3–3.5; G = 3.96. Color white, bluish, reddish; luster vitreous to pearly. Closely resembles barite, may be distinguished with the hand goniometer by measuring the angle of cleavage. Found in limestones, often with metallic ores. A source of strontium salts.

CALAMINE, G = 3.4–3.5 has been described under Division *1 e*.

b. Fracture columnar to fibrous.

Valentinite, Sb_2O_3, IV. Fibrous or lamellar massive. H = 2.5–3; G = 5.57. Color white, grayish; luster pearly. In tufts of crystals and massive, in crusts, on antimony ores, as Stibnite.

WITHERITE, $BaCO_3$, IV. Columnar massive, crystals pseudohexagonal. H = 3–3.5; G = 4.27–4.35. Color whitish, grayish, translucent; luster greasy. Fracture uneven columnar. Occurs with lead ores, etc.

STRONTIANITE, $SrCO_3$, IV. Columnar to fibrous massive. H = 3.5–4; G = 3.7. Color pale greenish, white, yellowish, luster vitreous to somewhat resinous. More fibrous and vitreous than Witherite.

Compare Calamine above, fibrous to columnar fracture, *see* Division *1 e*., also Cerussite below.

c. Compact.

Sphalerite, *Siderite* and *Rhodochrosite* occur in compact form, see above *a*. Also *Cerussite* is sometimes compact, see Division *d*.

d. Not included in the foregoing divisions; mostly crystalline.

Stolzite, $PbWO_4$, II. Acute pyramidal. H = 2.75–3; G = 7.9–8.1. Color yellowish gray, brownish, greenish; resinous to subadamantine. Generally in distinct, acute tetragonal pyramids. Rare.

Wulfenite, $PbMoO_4$, II. Tabular. H = 2.75–3; G = 6.7–7. Color yellow, orange, orange red, greenish; luster adamantine. Generally in crystals, rarely massive. With lead ores.

PYROMORPHITE, $Pb_5Cl(PO_4)_3$, III. In hexagonal prisms, with basal pinacoid; in crusts. H = 3.5–4; G = 6.5–7.1. Color green to yellow, brown, whitish; luster vitreous to resinous. Commonly in crystals, sometimes crystals barrel-shaped; occasionally compact fibrous, in crusts. A lead ore occurring near the surface.

Mimetite, $Pb_5Cl(AsO_4)_3$, III. Habit like the last; crystals sometimes in rounded, globular form; in crusts. H = 3.5; G = 7–7.25. Color yellow, orange, brownish; luster resinous. With lead ores, more rare than pyromorphite.

Vanadinite, $Pb_5Cl(VO_4)_3$, III. Habit like pyromorphite, generally in crystals; in crusts. H = 2.75–3; G = 6.7–7.1. Color red, brownish, yellow; luster adamantine, on fracture resinous. The variety *Endlichite* is intermediate in composition between vanadinite and mimetite, and closely resembles mimetite. Found with *lead ores in Arizona*, New Mexico, etc.

Descloizite, $Pb(OH).(Pb,Zn)VO_4$, IV. Habit pyra-

midal, resembling octahedrons; drusy. H = 3.5; G = 5.9–6.2. Color yellowish-brown, reddish-brown, brownish-black; luster adamantine to resinous; with lead and silver ores; found with the last. *Cuprodescloizite* is a massive variety containing copper, it occurs in crusts.

CERUSSITE, $PbCO_3$, IV. Habit prismatic, pseudohexagonal; crystals often twinned, and striated; also columnar to fibrous. H = 3–3.5; G = 6.46–6.57. Colorless, white, grayish, yellowish; luster pearly-adamantine, sometimes silky, resinous to greasy on fracture. The mineral is commonly in crusts, or massive aggregates of crystals; more rarely compact. As an ore, it is often colored by mechanical impurities. A common ore of lead, near the surface.

ANGLESITE, $PbSO_4$, IV. Habit tabular or short prismatic; rarely massive. H = 2.75–3; G = 6.3–6.4. Color grayish, white, colorless; luster vitreous to resinous, sometimes adamantine. Not pearly nor twinned like Cerussite, generally more grayish. With other surface lead ores, not so common as Cerussite.

III. Hardness 4.5 to 6.

1. The mineral or its fracture is columnar to fibrous.

a. Columnar, or in bladed crystals.

CYANITE, Al_2SiO_5, VI. In thin bladed crystals to fibrous. H = 5, parallel to the length of the crystals, 7 across the crystal. G = 3.56–3.67. Color blue, greenish-blue, green, gray, to colorless; luster vitreous, sometimes pearly. In gneiss and mica schist.

Anthophyllite, $(Mg,Fe)SiO_3$, IV. In aggregations of crystals, also fibrous massive. Cleavage when present *prismatic*, with angle of 125° 37′. H = 5.5; G = 3.1–

3.2. Color brownish-gray to yellowish-brown; luster vitreous, inclining to pearly. In mica schists, etc.

TREMOLITE, $CaMg_3Si_4O_{12}$, V. Commonly in bladed crystals or columnar to fibrous; cleavage, when distinguishable, prismatic with angle of 124°. H = 5–6; G = 2.9–3.1. Colorless to gray; vitreous. Common in metamorphosed limestones.

ACTINOLITE, $Ca(Mg,Fe)_3Si_4O_{12}$, V. Columnar or in bladed crystals. Cleavage as in Tremolite. H = 5–6; G = 3–3.2. Color bright green; luster vitreous. Grades into a green asbestus. With Talc and serpentine rocks.

HORNBLENDE. See (B. V, 3, a), also below. Some varieties are columnar or in bladed crystals. Hornblende generally has a colored streak.

b. In crusts with a fibrous structure.

CALAMINE. See (C. II, 1, e). Calamine is generally not above 4.5 in hardness.

Natrolite, $Na_2Al_2Si_3O_{10} + 2H_2O$, IV. Crystals slender to acicular, in crust-like aggregates and radiating, coarse to fine fibrous. H = 5–5.5; G = 2.2. Colorless or tinted by mechanical impurities. Luster vitreous, sometimes silky in fibrous specimens. A zeolite, commonly found in basalts and other basic igneous rocks.

c. Massive fibrous.

Pectolite, $HNaCa_2(SiO_3)_3$, V. Commonly in white radiating fibers or close aggregations of acicular crystals, which easily penetrate the skin when handling the mineral. H = 5; G = 2.68–2.78. Luster silky. In seams and masses in basic igneous rocks; formed by hydration like the zeolites.

Wollastonite, $CaSiO_3$, V. Fibrous and cleavable massive, *also in crystals.* H = 4.5–5; G = 2.8. Color

white, grayish, yellowish; luster vitreous. When in crystals, a good pinacoidal cleavage. In crystalline limestones altered by contact with granites, etc., along the zone of contact.

WERNERITE, $\left\{\begin{matrix} Ca_4Al_6Si_6O_{25} \\ Na_4Al_3Si_9O_{24}Cl \end{matrix}\right\}$ II. In 8-sided tetragonal prisms with pyramidal terminations, also massive, somewhat fibrous to granular. H = 5.5; G = 2.6–2.7. Color white, grayish, greenish, also rarely yellowish and lilac. Luster of crystals vitreous, or fracture greasy. The cleavage is prismatic, hence the fibrous appearance. In and near contact zones of granular limestone with granite, etc.

Tremolite, often massive fibrous, see above. Also *Hornblende*, below, 3.

NEPHELITE, var. ELAEOLITE, $K_2Na_6Al_8Si_9O_{34}$, III, hemimorphic. The variety Elaeolite is generally massive, or in rough crystals, with a somewhat fibrous fracture and greasy luster. H = 5.5–6; G = 2.55–2.65. Colorless, greenish-gray to bluish-green, reddish. In elaeolite-syenite.

ENSTATITE, $MgSiO_3$, and HYPERSTHENE, $(Mg, Fe)SiO_3$, IV. Crystals rare. Usually fibrous massive. The cleavage is prismatic, angle of 92°, also pinacoidal, making the fracture fibrous. H = 5.5; G for Enstatite = 3.1–3.3; for Hypersthene = 3.4–3.5. Color grayish to brownish for Enstatite; black, brownish or greenish-black for Hypersthene. As the iron-content increases the mineral often shows a coppery or bronzy reflection on some surfaces, characteristic of hypersthene and *Bronzite*, the intermediate between hypersthene and *enstatite*. Rock-making minerals in basic and ultra-basic igneous rocks. Altering to serpentine, talc, etc.

Apatite occurs as Phosphorite, massive fibrous, see below, 4.

2. Amorphous.

OPAL, $nSiO_2 + H_2O$. Compact amorphous or pseudomorphous, sometimes in crusts, stalactitic, botryoidal. H = 5.5–6; G = 1.9–2.3. White and colorless, also colored various shades by mechanical impurities. Precious opal shows a rich play of colors by reflected light; used as a gem. Common opal is compact and translucent with a subresinous luster. Other varieties are opal-jasper, wood-opal, hyalite or glassy opal, silicious sinter and geyserite, diatomaceous earth and tripoli (used for polishing powders), etc. Precious opal and common opal occur as hydration products in igneous rocks.

SERPENTINE, var. *Bowenite*, $H_4(Mg,Fe)_3Si_4O_9$, V. Compact massive, very fine granular. H = 5–5.5; G = 2.6–2.78. Pale yellowish or greenish-white; luster dull. Closely resembles some varieties of nephrite, and is one of the harder serpentine minerals, often called *Jade*. It is always softer than hard steel, and this will distinguish it from true jade.

3. Cleavable.

a. Color light.

TEPHROITE, Mn_2SiO_4, IV. Rarely in crystals, massive and often cleavable in two directions at right angles. H = 5.5–6; G = 4–4.12. Grayish flesh-red, ash-gray; darkening to brownish on exposure. Luster greasy. Occurs *associated with* Rhodonite, and at Franklin, *N. J., with the zinc* ores and Franklinite.

Compare also *Calamine*, *Cyanite*, *Wernerite*, and *Wollastonite* above.

DIOPSIDE, *light-colored Pyroxene*, $CaMgSi_2O_6$, V. In prismatic crystals and massive granular, with strong prismatic cleavage at an angle of 93°. H = 5–6; G = 3.2–3.4. Color generally some shade of green, also yellowish, grayish; luster vitreous. In crystalline limestone and other metamorphic rocks. The variety Coccolite is in roundish grains. *Fassaite* would belong here, light to bright green.

b. Color dark.

PYROXENE, AUGITE, $Ca(Mg,Fe)Si_2O_6 + (Mg,Fe)(Al,Fe)_2SiO_6$, V. In long or short prismatic crystals, with prismatic cleavage as in Diopside; also massive granular, or lamellar. H = 5–6; G = 3.2–3.55. Color black, brownish-black, greenish-black. Streak often colored. Luster vitreous. Resembles hornblende, from which it is distinguished by its more nearly rectangular cleavage. It is more liable to be brownish, while hornblende is greenish. It is rarely fibrous like hornblende. The common ferro-magnesian mineral in igneous rocks, also found in metamorphic rocks.

Aegirite and *Acmite*, *Alkali Pyroxene*, $NaFSi_2O_6$, V. Long or short prismatic, with prismatic cleavage, like pyroxene. H = 6–6.5; G = 3.5. Color black; streak generally colored, yellowish. Luster vitreous. Occurs in rocks high in soda, as nepheline-syenite, phonolite, etc.; also in granites.

HORNBLENDE, $\left\{\begin{matrix} Ca(MgFe)_3Si_4O_{12} \\ (MgFe)_2(AlFe)_4Si_2O_{12} \end{matrix}\right\}$ V. See (B.V. 3.*c*). In short to long prismatic crystals, cleavable to fibrous massive. Cleavage angle 124°. H = 5–6;

G = 3–3.5. Color greenish-black, black, in some cases brownish-black. Streak generally colored greenish. Luster vitreous. Resembles pyroxene, but has an obtuse or acute angle of cleavage, and is inclined to be fibrous, and more greenish. A common rock-making mineral in metamorphic rocks, as gneisses and schists; also in some igneous rocks.

Perovskite, see below; cleavable, but generally in good crystals.

4. Not belonging to the foregoing divisions.

a. In distinct crystals. The following are grouped according to crystallization:

Analcite, $NaAlSi_2O_6 + H_2O$, I. In trapezohedrons, usually lining cavities; the crystals sometimes grow together to a granular mass. H = 5–5.5; G = 2.2–2.3. Colorless to white, very vitreous. Fracture conchoidal. Occurs with other zeolites in altered igneous rocks.

Perovskite, $CaTiO_3$, I. In cubes and cubo-octahedrons, disseminated; cleavage cubic. H = 5.5; G = 4. Color yellowish, brownish, grayish-black. Luster submetallic-adamantine. Here also belongs *Dysanalyte*, titano-niobate of calcium and iron, which closely resembles Perovskite. Rare.

SODALITE, $Na_4(AlCl)Al_2(SiO_4)_3$, I. In dodecahedrons, also massive granular. H = 5.5–6; G = 2.14–2.3. Color bluish, gray, white. Luster greasy to vitreous. A rock-making mineral in nepheline-syenite rocks; often in roundish grains. Closely related is Hauynite, also bluish.

LEUCITE, $KAlSi_2O_6$, I. In trapezohedrons, crystals often rough and dull on the surface. H = 5.5–6, G = 2.45–2.5. Colorless, ash gray. Luster on fracture

vitreous; fracture conchoidal. Harder than *analcite*. Occurs only in igneous rocks, especially recent lavas.

Melilite, $Na_2(Ca,Mg)_{11}(Al,Fe)_4(SiO_4)_9$, II. In square or octagonal prisms, or tabular by development of the basal pinacoid; disseminated. H = 5; G = 2.9–3.1. Colorless, yellowish, brownish, grayish; luster greasy. A rock-making mineral in igneous rocks high in lime, alumina and magnesia.

WERNERITE (see above), often in distinct crystals.

APATITE, $Ca_5(Cl,F)(PO_4)_3$, III. In hexagonal prisms, also granular massive, no distinct cleavage, fracture conchoidal to uneven. H = 5; G = 3.2. Color bluish green, white, reddish. Luster subresinous to greasy. An important source of *phosphoric acid*. Generally in metamorphic limestones. Apatite also occurs in compact and fibrous forms, as *osteolite*, *phosphorite*, etc., and in fossil bones. Used for fertilizers, etc.

WILLEMITE, Zn_2SiO_4, III R. In hexagonal prisms, also massive and granular. H = 5.5. G = 3.9–4.2. Colorless, yellowish, greenish, reddish. Luster subresinous to greasy. An important ore of zinc at Franklin Furnace, N. J., with franklinite, zincite, etc. Rare in Colorado and New Mexico. The subresinous luster and hardness characterize the mineral.

NEPHELINE, $(Na_2,K_2,Ca)_4Al_8Si_9O_{34}$, III, hemimorphic. See above (1 *c*). The ordinary nepheline of phonolites, etc., is in distinct, short, hexagonal prisms, disseminated. Colorless or yellowish. Luster vitreous. As seen in the rock the cross section is usually hexagonal or rectangular. A rock-making mineral in certain igneous rocks.

Monticellite, $CaMgSiO_4$, IV. In short orthorhombic

crystals, in grains, massive granular. H = 5–5.5; G = 3–3.25. Yellowish gray, colorless, brownish. Luster sub-resinous. A rather rare member of the chrysolite group in metamorphic granular limestone.

Tephroite, Mn_2SiO_4, IV. See (3. *a.*) above. Crystals rare.

Natrolite. See (1.*b.*) above. When in distinguishable crystals has a *tetragonal* appearance, four-sided prisms terminated by flat four-sided pyramids.

Monazite, $(Ce, La, Di)PO_4$, V. In disseminated crystals and grains, also in sands. H = 5–5.5; G = 4.9–5.3, heavy. Color yellowish brown, reddish, yellow; luster sub-resinous to greasy, often dull. An accessory constituent of some gneisses and granites, and in their residual sands. Used for incandescent gas-light mantles, etc.

DATOLITE, $HCaBSiO_5$, V. In short crystals, aggregated to form granular crusts lining seams in the rock; sometimes compact. H = 5–5.5; G = 3. Colorless, greenish. Luster very glassy. A secondary mineral in basic igneous rocks such as gabbro, diabase and basalt; occurs with zeolites.

Lazulite, $(FeMg)Al_2(OH)_2(PO_4)_2$, V. Crystals pyramidal, resembling acute tetragonal pyramids. H = 5–6; G = 3. Color azure blue, distinguishing the mineral; streak not colored. Luster vitreous. Occurs with feldspar, cyanite, etc., in granites and gneisses. Rare.

ALLANITE. See under green streak (B.V.3.*b*). This mineral sometimes has an uncolored streak.

b. Massive.

The following minerals mentioned above occur in massive form: Sodalite, Hauynite, Wernerite, Apatite,

Willemite, Elaeolite, Monticellite, Tephroite, Allanite, Monazite. Here also belongs:

Cancrinite, $H_6Na_6Ca(NaCO_3)_2Al_6(SiO_4)_6$, III. Almost always massive. H = 5–6; G = 2.4–2.5. Color honey yellow, also white, gray, reddish. Luster greasy. Gives off CO_2 with acids like carbonates. In igneous rocks containing nepheline, such as nepheline-syenite. Often associated with sodalite.

IV. Hardness 6 to 7, scratched by quartz, but not by a knife (or only with much difficulty).

1. Readily cleavable, with smooth cleavage faces.

a. Color light.

Amblygonite, $Li(AlF)PO_4$, VI. Crystals rough, not common; cleavage basal, perfect, also macro-pinacoidal, angle 75° between cleavages. H = 6; G = 3. Colorless, white, greenish. Luster vitreous to pearly. Resembles feldspar in appearance but has a different angle of cleavage. Rather rare.

Petalite, $LiAl(Si_2O_5)_2$, V. Crystals rare. Foliated cleavable massive, cleavage basal, perfect. H = 6–6.5; G = 2.4–2.45. Colorless, white, greenish. Resembles the last, but more foliated, and generally shows but one cleavage. Rather rare.

Zoisite, $HCa_2Al_3Si_3O_{13}$, IV. In long striated prismatic crystals, with strong brachypinacoidal cleavage, along the length of the prism; crystals aggregated to columnar massive form. H = 6–6.5; G = 3.25–3.35. Color grayish, brownish or greenish gray; luster pearly on cleavage face, otherwise vitreous. Resembles light colored amphiboles and pyroxenes, but distinguished

by the cleavage. Found as a metamorphic rock-making mineral in schists and gneisses.

FELDSPAR GROUP. The feldspars may be divided into two groups, one *monoclinic or pseudomonoclinic*, including ORTHOCLASE and MICROCLINE; the other *triclinic* and including the ALBITE-ANORTHITE series called in general PLAGIOCLASE. All are characterized by two cleavages at right angles or nearly so; with hardness from 6 to 6.5.

ORTHOCLASE V and MICROCLINE VI (pseudomonoclinic), $(K,Na)AlSi_3O_8$. In distinct crystals, often rough, also massive; crystals twinned, generally in Carlsbad and Baveno twins. Cleavages at 90°. In the glassy variety, *sanidine*, found in volcanic rocks, the crystals are often very perfect. In the varieties from deep-seated rocks the crystals are rough and intersected by wavy cracks filled with some other mineral, these cracks running across the cleavage faces. The cleavage faces are not striated with parallel lines, like rulings, as in most *plagioclase*. H = 6; G = 2.57. Colorless in *sanidine* and *adularia*, yellowish, reddish, light gray in common *orthoclase* and *microcline;* also green in some microcline, "amazon stone." Luster vitreous, to somewhat pearly on the cleavage; becoming dull and chalky by alteration. Very important rock-making minerals in acid igneous and many metamorphic rocks, as granite, syenite, gneiss, etc.

PLAGIOCLASE. The ALBITE, $NaAlSi_3O_8$—ANORTHITE, $CaAl_2Si_2O_8$, series, VI. Cleavages inclined at angles varying from 86° 24′ (*Albite*) to 85° 50′ (*Anorthite*) distinctly not at right angles. Cleavage faces generally striated with parallel lines due to twinning. H = 6–6.5

except sometimes *Andesite* and *Labradorite*, which are occasionally soft enough to be scratched by a knife. G = 2.65 (*Albite*)—2.76 (*Anorthite*). The principal members of the plagioclase group are given below; Ab = albite, An = anorthite.

ALBITE, $NaAlSi_3O_8$, VI. In crystals or massive and granular; colorless to white and greenish, sometimes with a bluish opalescence, as in the variety *moonstone*. Twin striation generally marked. A rock-making mineral in syenites, granites, gneisses.

OLIGOCLASE, 3 Ab: 1 An. Closely resembling albite, and associated with it in the same rocks. Often very glassy and greenish, sometimes in variety *moonstone*, or with enclosed scales of hematite or goethite in *sunstone*.

ANDESITE, 3 Ab: 1 An to 1 Ab: 1 An. Commonly cleavable granular. Twin striations generally present. A characteristic mineral in the *intermediate* igneous rocks.

LABRADORITE, 3 Ab: 4 An to 1 Ab: 3 An. Crystals generally thin tabular, showing as "*lath-shaped*" crystals when seen in fractured sections in the rocks; also in large rough crystals and masses, and granular. In the larger massive specimens a play of colors is often seen when the mineral is held in certain positions. Color of the mineral gray to greenish. The common rock-making feldspar in basic igneous rocks, such as gabbro, diabase, basalt, etc.

ANORTHITE, $CaAl_2Si_2O_8$, VI. Crystals short prismatic. Color white, greenish; sometimes quite vitreous, generally rather dull. A rather uncommon rock-making mineral in *basic* and *intermediate* igneous rocks.

Compare also *Diopside*, often harder than steel; also *Spodumene*, see below (2) sometimes cleavable.

b. **Color, dark.**

EPIDOTE, $HCa_2(Al,Fe)_3Si_3O_{13}$, V. Crystals long prismatic, striated; cleavage basal, along the length of the crystal, also fibrous and columnar, sometimes compact fibrous and granular massive. H = 6.5; G = 3.4. Color pistachio-green, yellow-green, greenish-black. Luster vitreous to subresinous. Occurs as a rock-making mineral in mica schists, gneisses and other metamorphic rocks; a result of the metamorphism.

Compare also Pyroxene and Acmite, which are sometimes harder than steel.

2. Fracture fibrous or columnar.

SPODUMENE, $LiAlSi_2O_6$, V. In flattened prismatic crystals, often vertically striated, with cleavage parallel to the prism, angle of 93°; generally looking fibrous to columnar on the fracture. H = 6.5–7; G = 3.1–3.2. Color grayish-white, greenish-white; the variety *Hiddenite*, used as a gem, is emerald-green. Luster vitreous, also pearly and silky. In granitoid rocks.

FIBROLITE, SILLIMANITE, Al_2SiO_5, IV. In slender striated prisms or in parallel fibers forming masses; sometimes columnar. H = 6–7; G = 3.24. Color gray, brownish-gray, dirty white; luster vitreous to silky. In gneisses, generally in the quartz veins.

Nephrite, Jade, $CaMg_3(SiO_3)_4$, V. Compact fibrous. H = 6–6.5; G = 3. A compact variety of Tremolite that is harder than steel. This is one of the minerals known as Jade. Another is *Jadeite*, $NaAlSi_2O_6$, V, a pyroxene. They are very similar in appearance. Colors dull gray green to oil green and leek green; taking a high polish. Very tough. Closely resemble serpentine,

but are much harder. Used extensively by aborigines for cutting-tools and ornaments.

QUARTZ, SiO_2, III R. Cryptocrystalline varieties are fibrous in some cases. See below. Such varieties are *Chalcedony*, *Agate*, *Silicious sinter* and some pseudomorphous forms.

Compare *Enstatite*, *Hypersthene* and *Prehnite*, hardness below 6, but sometimes also above 6.

Compare also *Zoisite* and *Epidote* above, which are often fibrous.

3. In distinct crystals. These are arranged according to the system of crystallization.

Boracite, $Mg_7Cl_2B_{16}O_{30}$, I. In cubes, dodecahedrons, octahedrons and their combinations. No distinct cleavage, fracture subconchoidal. H = 7; G = 3. Colorless, grayish, greenish; luster high vitreous. Sometimes massive. With anhydrite and gypsum in salt deposits.

GARNET, $R_3''R_2'''(SiO_4)_3$, I. In dodecahedrons and trapezohedrons; fracture uneven to subconchoidal; also sometimes granular massive H = 6.5-7.5; G = 3.1-4.3. The principal sub-species of garnet are as follows:

GROSSULARITE, $Ca_3Al_2(SiO_4)_3$. Colorless, yellowish-white, pale green, brownish-red, rose-red. Colors mostly pale. In metamorphosed calcareous rocks.

PYROPE, $Mg_3Al_2(SiO_4)_3$. Deep ruby red. Gem garnet. In altered magnesian igneous rocks.

ALMANDITE, $Fe_3Al_2(SiO_4)_3$. Color deep red to purplish-red; used for gems. Very common in mica schists, gneisses and other metamorphic rocks; also in granites.

SPESSARTITE, $Mn_3Al_2(SiO_4)_3$. Color dark brownish-red. *In granites and gneisses.*

ANDRADITE, $Ca_3Fe_2(SiO_4)_3$. Color yellow, brown, brownish-red, also many shades of yellow-green and green. *Demantoid*, emerald green, is a valuable gem. *Topazolite* is topaz yellow.

Melanite is black; it generally contains Titanium. In granite, gneiss, also in metamorphosed limestones.

Uvarovite, $Ca_3Cr_2(SiO_4)_3$. Color emerald green. Streak greenish. With chromite.

CASSITERITE, SnO_2, II. In obtuse and acute pyramidal crystals, generally twinned. Also massive granular, in loose grains. H = 6–7; G = 6.8–7.1, *very heavy*. Color brownish to black; by transmitted light yellowish to brownish. Luster adamantine to resinous. Its very high specific gravity and brownish color distinguish it. In micaceous rocks as gneiss, granite, mica schist; also in stream gravels. Associated with quartz, wolframite, columbite, tourmaline and mica. The principal ore of tin.

RUTILE, TiO_2, II. In striated prisms, many times twinned; in eight-sided prisms with flat pyramidal termination; rarely compact massive. H = 6–6.5; G = 4.2–4.3. Color reddish-brown to black, by transmitted light deep red. Streak often brownish. Luster adamantine. Resembles cassiterite, but has a lower specific gravity; red by transmitted light, and crystals are more prismatic. Occurs in granite, gneiss, syenite, mica schist and granular limestone.

VESUVIANITE, $Ca_{24}Al_{13}(OH)_{20}Si_{20}O_{77}$, II. In square and octagonal prisms with pyramidal terminations; sometimes the crystals aggregate into crusts. H = 6.5; G = *3.35–3.45. Color brownish-green; yellow green, more rarely brown, yellow*, blue. Luster vitreous to sub-

resinous. A mineral found in altered limestone, along contacts with igneous rocks.

QUARTZ, SiO_2, III, R. Trapezohedral. In hexagonal prisms terminated by rhombohedrons; the prism faces are horizontally striated; also in many other forms enumerated below. H. = 7; G = 2.65–2.66. Colorless and variously colored by mechanical impurities. Luster vitreous. The following are the principal varieties of crystalline quartz; the crypto-crystalline varieties are given under *Division 5, compact massive:*

ROCK CRYSTAL. Colorless; usually in crystals forming crusts, when small the surface becomes *drusy*. Common in mineral veins.

AMETHYST. Color purple to violet. Color said to be due to manganese. A gem.

ROSE QUARTZ, pink or rose color; said to be colored by titanium.

SMOKY QUARTZ, brownish to blackish, used as a gem under the name of *cairngorm;* and yellow, used as a gem under the name of *false topaz* or *citrine*. The color is probably due to bitumen or other organic compound.

MILKY QUARTZ. Milk-white, due to minute cavities.

Rutilated quartz, Cat's-eye, Tiger's-eye, with enclosed fibrous minerals, giving it a *chatoyant* luster.

Ferruginous, Chloritic, etc,, with distinct mineral impurities, giving it the name.

Here would belong *granular quartz,* but it generally does not show any crystal faces; see under *Fracture granular, generally massive,* below.

TITANITE, $CaTiSiO_5$, V. In flattened, wedge-shaped monoclinic crystals, often twinned; with adamantine to

high resinous luster. H = 5.5–6.5; G = 3.4–3.56. Color commonly brown, also yellow, yellow-green, reddish, black; when transparent a fine gem. An accessory mineral in the plutonic igneous rocks, commoner in the feldspathic rocks; also in the metamorphic limestones.

AXINITE, $H(Ca,Fe)(Al,B)_3(HAlSiO_3)(SiO_4)_5$, VI. In very oblique, acute-edged crystals, sometimes also massive. H = 6.5–7; G = 3.3. Color clove to violet brown, gray, yellow. Luster vitreous to subadamantine. Rather rare.

Compare *Staurolite* (H=7.5) which is often soft on the exterior of the crystal; also *Chondrodite* below, which is sometimes in distinct crystals; and *Zircon* (H = 7–7.5).

4. Usually massive; fracture granular.

CHRYSOLITE $(Mg,Fe)_2SiO_4$, IV. In imbedded grains and massive granular; crystals rare. H = 6.5–7; G = 3.25–3.37. Color olive to yellow green. Luster vitreous to subresinous or greasy. A rock-making mineral in basic and ultrabasic igneous rocks; also rarely a metamorphic mineral in certain altered dolomites. When transparent, a gem under the names *Peridote*, *Chrysolite*, etc. Closely related are *Hortonolite*, $(Fe,Mg,Mn)_2SiO_4$, and *Fayalite*, Fe_2SiO_4, which occur in the same form as chrysolite, but are dark brownish to black. *Forsterite*, Mg_2SiO_4, IV, belongs to the chrysolites; it is white to light greenish. Found in metamorphosed limestones.

CHONDRODITE, $[Mg(F,OH)]_2Mg_3(SiO_4)_2$, V. Commonly massive granular or in disseminated grains, or roundish crystals. H = 6–6.5; G = 3.1–3.2. Color

honey-yellow, light yellow, chestnut brown, reddish. Luster sub-resinous to vitreous. A metamorphic mineral in many altered limestones. Here also belong *Clinohumite* and *Humite*, of similar composition to *chondrodite* (many "chondrodites" being mixtures with one of these) and occurring in the same associations; all alter to and are associated with the serpentine minerals, chlorite, etc.

Compare also *granular quartz*, *cassiterite*, and *garnet*, which occur massive granular.

5. Compact massive.

Turquois, $Al_2(OH)_3PO_4 + H_2O$. Compact, cryptocrystalline; in seams and disseminated grains. H = 6; G = 2.6–2.8. Color blue, greenish-blue to apple-green. Luster dull, waxy; takes a good polish. When of good color used for a gem. Occurs in altered trachyte rocks.

QUARTZ, SiO_2. Cryptocrystalline varieties, H = 7 or a little above, often scratching quartz. These are mostly compact massive. The following are the principal varieties (see also under *Quartz* above):

CHALCEDONY. Colors dull, grayish, bluish; not banded or mottled. Luster waxy. In crusts and forming geodes, etc. *Chrysoprase* is pale apple-green, from NiO.

CARNELIAN, SARD. Translucent red to brownish-red.

HELIOTROPE or BLOODSTONE, bright leek green, with red spots due to hematite.

AGATE, banded or variegated in several colors.

ONYX, like agate but the colors arranged in parallel *plane layers*. *Sardonyx* has layers of carnelian with *white intermediate* layers.

JASPER, opaque, generally strongly colored.

FLINT, HORNSTONE, somewhat translucent, dull colored.

Basanite, Touchstone, like flint but black; used for testing gold alloys by *test needles*.

Compare also *nephrite* above which is compact, and in which sometimes the fibrous character is not evident.

V. Hardness 7.5 or above, scratch quartz with ease. Arranged according to their crystallization.

SPINEL, $MgAl_2O_4$, I. In octahedrons, often twinned, also in parallel groupings. H = 8; G = 3.5–4. The Mg is sometimes replaced by Fe, Mn, and the Al by Fe, Cr. Colors vary with the composition, producing varieties. Luster vitreous. The following are the principal varieties:

Ruby Spinel, Balas Ruby, $MgAl_2O_4$. Clear rose to red. Used as a gem.

COMMON SPINEL, $MgAl_2O_4$. Gray, greenish, purplish.

PLEONASTE $(Mg,Fe)(Al,Fe)_2O_4$. Dark green to black.

Picotite, Chrome Spinel, $Mg(Al,Cr)_2O_4$. Dark greenish to black.

Hercynite, $FeAl_2O_4$. Black, generally pseudomorphous after corundum, etc.

Gahnite and *Dysluite* $(Zn,Fe,Mn)(Al,Fe_2)O_4$. Green, yellow green, bluish, greenish black.

The spinels are generally found in isolated crystals in granular metamorphosed limestones; often associated with chondrodite, titanite, etc.

DIAMOND, C. I. In octahedrons, hexaoctahedrons; *cleavage octahedral.* H = 10; G = 3.52. Colorless,

gray or black. Luster adamantine. Crystals generally with rounded faces. Easily distinguished by its great hardness. When clear a valuable gem; the roughly crystallized material or *bort*, and the black or *carbonado* are used for boring stone (*diamond drills*), etc. Found in river gravels and in certain basic igneous rocks.

Compare GARNET, I., which often scratches quartz with ease.

ZIRCON, $ZrSiO_4$, II. In short square prisms terminated by square pyramids, also in grains. H = 7.6; G = 4.7. Luster adamantine to resinous. Color grayish brown, reddish gray to brownish, sometimes transparent red-brown as a gem (hyacinth). A constituent in the acid igneous and metamorphic rocks. Used in making incandescent gas-light mantles. Found in *monazite* sand, with *Thorite*, etc.

TOURMALINE, $(H_2, Li, Na_2, Fe.Mg.[AlO]_2)_3(AlO.BO)(SiO_4)_2$, III R. Hemimorphic. Crystals prismatic, generally 3 to 9 sided to many-sided; long, striated parallel to the length, and often broken transversely in the rock; sometimes in short prisms. Terminations unlike on the opposite ends of the same crystal. H = 7–7.5; G = 3–3.2. Black, green and brown are the most common colors, also rose, pink, blue, colorless. Luster vitreous. A rock-making mineral (accessory constituent), in granite, gneiss, mica schist, altered limestone, etc. The black tourmaline is *Iron Tourmaline*, the brown and some green are *Magnesium Tourmaline*, while the rose, red, blue and some green shades are *Lithia Tourmaline*. The clear varieties are sometimes used for gems.

BERYL, $Be_3Al_2(SiO_3)_6$, III. In hexagonal prisms; when terminated, generally by the basal pinacoid.

More rarely massive. H = 7.5–8; G = 2.65–2.8. Generally pale green to bluish-green, also emerald green, light blue, yellow; luster vitreous. *Emerald*, the gem, is beryl colored by a little Cr. Other varieties used as a gem are *aquamarine*, bluish green; *golden beryl*, yellow, also the common *beryl*, pale green. Beryl closely resembles *apatite* but is readily distinguished by its greater hardness. Common in the veins of *giant granite;* also in mica schists, etc.

Phenacite, Be_2SiO_4, III R. In rhombohedra, etc. H = 7.5–8; G = 3. Colorless, also brown, brownish-yellow. Luster vitreous. Looks much like quartz. Rather rare.

CORUNDUM, Al_2O_3, III R. In barrel-shaped and tapering six-sided crystals, often with strong basal and rhombohedral parting, also massive, granular disseminated. The parting or pseudocleavage makes angles of 93°, nearly cubical. H = 9; G = 3.95–4.1. Luster adamantine to high vitreous. Colors various. The following varieties have been distinguished.

CORUNDUM. Colors dull, often dark, not transparent but translucent. Generally gray, yellowish, bluish, greenish. Used for an abrasive material, also an aluminium ore.

RUBY, red; SAPPHIRE, blue; ORIENTAL EMERALD, green, valuable gems; the transparent varieties. The name sapphire as a general term includes also purplish, greenish and pinkish kinds.

EMERY. Impure from admixture of Fe_2O_3, or magnetite; black or brownish-black in color. Used for an *abrasive material.*

Corundum occurs in acid and basic igneous rocks,

crystallized from the magma, also in metamorphosed limestones, in gneiss, etc.; with spinel, magnetite, etc.

STAUROLITE, $HFeAl_5Si_2O_{13}$, IV. In flattened prisms, angle 129° or six-sided by development of the brachypinacoid, very commonly twinned in + or × shaped twins. Surface of crystals often rough with mica inclusions. H = 7–7.5; G = 3.65–3.75. Color brown, reddish-brown to brownish-black; by transmitted light brownish-red to yellow-brown in thin splinters. Luster sub-resinous; greasy on fracture. A metamorphic rock-making mineral in mica schists and gneisses.

ANDALUSITE, Al_2SiO_5, IV. In nearly square prisms, sometimes massive columnar. H = 7.5; G = 3.2. Colors gray, whitish, rose, brownish; sometimes with the axis of the crystal and the angles of a different color from the rest (*macle*). Luster vitreous to dull. The apparent hardness of the exterior of the crystal often much below 7, due to alteration to mica. A metamorphic rock-making mineral found in mica schists developed from clay rocks; also found associated with granite.

TOPAZ, $Al_2(F.OH)_2SiO_4$, IV. In 8-sided prisms with various terminations; also occasionally columnar massive. Cleavage basal, perfect. H = 8; G = 3.5. Color wine yellow, straw yellow, greenish, bluish, colorless. Luster high vitreous. A gem when clear. In granite and other acid rocks.

Chrysoberyl, $BeAl_2O_4$, IV. Pseudohexagonal by twinning, in six-sided striated plates. In crystals resembling hexagonal pyramids. H = 8.5; G = 3.5–3.8. Color yellow-green, yellow, emerald-green (*alexandrite*); sometimes red by transmitted light. In granite, gneiss. *When clear* used as a gem.

APPENDIX I.

TABLE OF THE ATOMIC WEIGHTS OF THE ELEMENTS, ON THE BASIS OF OXYGEN (O) = 16. GIVING THE ATOMIC WEIGHT ACCORDING TO THE REPORT OF THE INTERNATIONAL COMMITTEE ON ATOMIC WEIGHTS, 1908.

Name of Element.	Symbol.	At. Wt.
Aluminium	Al	27.1
Antimony (Stibium)	Sb	120.2
Argon	Ar	39.9
Arsenic	As	75.0
Barium	Ba	137.4
Beryllium (Glucinum)	Be (Gl)	9.1
Bismuth	Bi	208.0
Boron	B	11.0
Bromine	Br	79.96
Cadmium	Cd	112.4
Caesium	Cs	132.9
Calcium	Ca	40.1
Carbon	C	12.00
Chlorine	Cl	35.45
Chromium	Cr	52.1
Cobalt	Co	59.0
Copper	Cu	63.6
Dysprosium	Dy	162.5
Erbium	Er	166.
Europium	Eu	152.
Fluorine	F	19.0
Gadolinium	Gd	156.
Gallium	Ga	70.0
Germanium	Ge	72.5
Gold (Aurum)	Au	197.2
Helium	He	4.0
Hydrogen	H	1.008
Indium	In	115.
Iodine	I	126.97
Iridium	Ir	193.0

APPENDIX I.—*Continued.*

Name of Element.	Symbol.	At. Wt.
Iron (Ferrum)	Fe	55.9
Krypton	Kr	81.8
Lanthanum	La	138.9
Lead (Plumbum)	Pb	206.9
Lithium	Li	7.03
Magnesium	Mg	24.36
Manganese	Mn	55.0
Mercury (Hydrargyrum)	Hg	200.0
Molybdenum	Mo	96.0
Neodymium	Nd	143.6
Neon	Ne	20.
Nickel	Ni	58.7
Niobium (Columbium)	Nb (Cb)	94.
Nitrogen	N	14.04
Osmium	Os	191.0
Oxygen	O	16.00
Palladium	Pd	106.5
Phosphorus	P	31.0
Platinum	Pt	194.8
Potassium (Kalium)	K	39.15
Praseodymium	Pr	140.5
Radium	Ra	226.45
Rhodium	Rh	103.0
Rubidium	Rb	85.5
Ruthenium	Ru	101.7
Samarium	Sm	150.3
Scandium	Sc	44.1
Selenium	Se	79.2
Silicon	Si	28.4
Silver (Argentum)	Ag	107.93
Sodium (Natrium)	Na	23.05
Strontium	Sr	87.6
Sulphur	S	32.06
Tantalum	Ta	181.
Tellurium	Te	127.6
Terbium	Tb	159.2
Thallium	Tl	204.1
Thorium	Th	232.5
Thulium	Tu	171.
Tin (Stannum)	Sn	119.0
Titanium	Ti	48.1

APPENDIX I.—(*Concluded*).

Name of Element.	Symbol.	At. Wt.
Tungsten (Wolframium).	W	184.0
Uranium.	U	238.5
Vanadium	V	51.2
Xenon.	Xe	128.
Ytterbium	Yb	173.0
Yttrium	Y	89.0
Zinc.	Zn	65.4
Zirconium	Zr	90.6

APPENDIX II.

GRADUATIONS FOR POLLOCK'S PROSPECTORS' DENSITY RULE. (SEE p. 220, ALSO TRANS. AMER. INST. MINING ENGINEERS, VOL. XXIX, p. 284.)

Specific Gravity Mark.	Distance from the End in Centimeters.	Specific Gravity Mark.	Distance from the End in Centimeters.
1.1	9.091	3.4	2.941
.2	8.333	.6	2.778
.3	7.692	.8	2.632
.4	7.143	4.0	2.500
.5	6.667	.2	2.381
.6	6.250	.4	2.273
.7	5.882	.6	2.174
.8	5.555	.8	2.083
.9	5.263	5.0	2.000
2.0	5.000	.5	1.818
.1	4.762	6.0	1.667
.2	4.545	.5	1.538
.3	4.348	7.0	1.428
.4	4.167	8.0	1.250
.5	4.000	9.0	1.111
.6	3.846	10.0	1.000
.7	3.704	12.0	.833
.8	3.571	14.0	.714
.9	3.448	16.0	.625
3.0	3.333	18.0	.556
.2	3.125	20.0	.500

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